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Beaver River Supply and Low-Flow Augmentation

By C. H. Young

THE Beaver River, one of the important tributaries of the Ohio River, is located in western Pennsylvania and is one of the larger river systems of the state. At its confluence with the Ohio River, 24 miles downstream from Pittsburgh, the Beaver has a drainage area of 3,100 square miles. Its two main tributaries are the Shenango River, which rises in northwestern Pennsylvania about 30 miles south of Lake Erie, and the Mahoning River, which rises in east central Ohio, west of Alliance, Ohio. These tributaries join below New Castle, Pennsylvania, and have a drainage area of about 1,090 square miles each. It is estimated that there is a population of 725,000 located on the Beaver River drainage area, which gives it a population density greater than that of either Pennsylvania or Ohio. Some of the more important municipalities on this river system are: Beaver Falls, New Castle, Ellwood City, Butler, Sharon, Farrell, in Pennsylvania; and Youngstown, Warren, Niles, Girard, and Alliance in Ohio. See fig. 1 for map of the Beaver River drainage basin.

The Beaver River drains a highly industrialized area in which steel production and fabrication and related industries predominate, although there is a wide variety of other industries including oil and oil refining, a limited coal production, chemicals manufacturing,

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A paper presented at the Central States Section meeting at Wheeling, W. Va., August 17, 1938, by C. H. Young, District Engineer, Pennsylvania Dept. Health, Meadville, Pa.

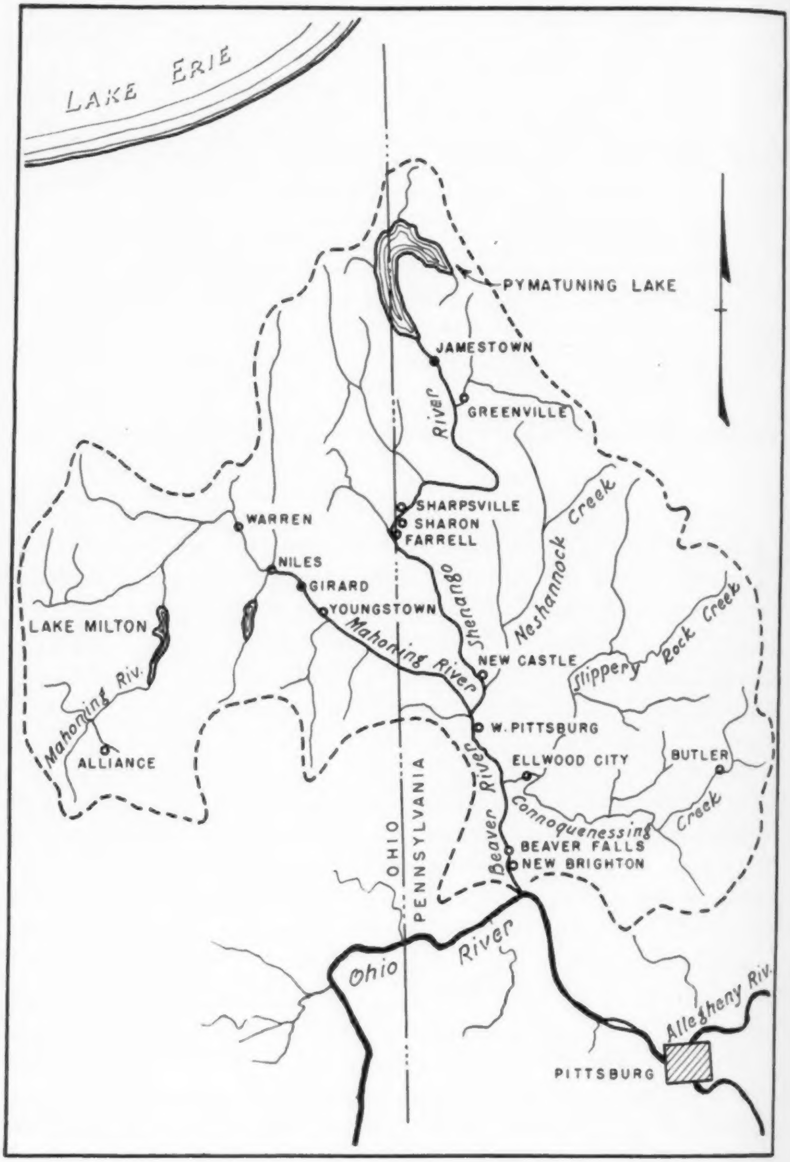

Fig. 1. Beaver River Drainage Basin

dairying, tanning, and manufacturing of cork, tar, cement, brick and tile products. There is a total of seventy municipalities on the watershed, forty-one of which are served with public sewer systems. The total sewered population is about 500,000. Of this total, 200,000 are in Pennsylvania, and 300,000 in Ohio.

The Beaver and Shenango Rivers and other of their tributaries in Pennsylvania serve as sources of public water supply for all of the larger municipalities on the drainage area in Pennsylvania. The Shenango River above the Sharon-Sharpsville-Farrell district is now being used increasingly for recreational purposes. The main river below this district is used but little for recreation, although this is an important summertime use for a number of the Pennsylvania tributaries of the Beaver and Shenango Rivers.

Second only to its use for public water supplies, is its use in industry and for cooling purposes. In the Sharon-Farrell district, prior to the completion of the Pymatuning Dam, and also in the Youngstown district, the entire low river flows have been used over and over again. Repeated use of the river water on low flows frequently raised the temperature to a range of 125° to 140° Fahrenheit at points of maximum use, thus causing industries temporarily to discontinue operation.

Years of discussion and activity finally resulted in Pennsylvania converting the Pymatuning swamp into a storage reservoir, by the construction in 1932 and 1933 of a dam across the upper Shenango River near Jamestown. The reservoir thus created has an area at spillway elevation of 28 square miles, a capacity of 75,000 million gallons, and a drainage area above the spillway of 150 square miles. This reservoir is a number of times larger, both from the standpoint of area and capacity, than the largest natural lake in Pennsylvania.

Purpose of Dam to Store Wet Weather Flows

The primary purpose of this dam is to store wet weather stream flows and to release these during dry weather periods, thereby providing not only adequate domestic supplies but also industrial water supplies in the Shenango and Beaver River valleys, at the same time increasing dilution of sewage and industrial wastes and also serving to reduce floods.

Approximately 60 per cent of the reservoir site was swamp land, and a considerable amount of the flooded land was a rich muck bottom land. Since the drainage from the swamp areas at certain

times of the year markedly affected the river water from the standpoint of color and tastes and odors, it was to be expected that the construction of the dam, with the flooding of swamps, would increase these difficulties, possibly for some years.

The principal water works in Pennsylvania on the Beaver drainage area, having filtration plants, are located at Sharon, New Castle, Ellwood City, West Pittsburgh, Beaver Falls, and New Brighton. These serve a population of about 170,000. It is estimated that a sewered population of about 470,000 persons discharges sewage to the Beaver River above the water works intakes. In addition, substantial volumes of industrial wastes, both in Pennsylvania and Ohio, are discharged into the river, and some of these (phenols) are extremely objectionable from the standpoint of taste and odor.

The Mahoning River in Ohio is comparable to the Shenango in Pennsylvania, with the exception that there is not as much swamp land on the drainage area. However, the greater density of population and the larger and more concentrated industrial development on the Mahoning make the effect of this stream on the Beaver River pronounced. The Mahoning River low flows are augmented to some extent by water released from the Milton Reservoir.

It is apparent that natural conditions, principally the effects from the swamp lands, the extensive discharge of industrial wastes on the watershed and the discharge of large volumes of raw and treated sewage, with the added complication of a drainage area in two states, all combine to produce a difficult stream control problem. And this problem is more than ordinarily difficult from the standpoint of the water filtration plants.

Programs Control Phenols and Wastes

Some years ago a control program was instituted, by agreement with the Ohio State Health Department, which provided for the elimination of the discharge of phenols and similar taste and odor producing substances. This was followed by a Pennsylvania program, now nearing completion, for the treatment of the municipal sewage and industrial wastes discharged to the tributary streams. Such a program was carried out on both the Shenango and Beaver Rivers in Pennsylvania to reduce the pollution load on these streams. This program was based upon the early construction of the Pymatuning Dam to increase low stream flows.

The 25-year low stream flow at Sharon from a drainage area of

608 square miles, is 8.2 cubic feet per second; the six-week sustained low flow is 23 c.f.s. or less. Following the filling of the dam and its placement in service in 1936, it will be noted from fig. 2 that the minimum flow for 1936 at Sharon was 85 c.f.s., and for 1937, 114 c.f.s. The low flow for the first six months in 1938 was 123 c.f.s. The stream control program has been based on a minimum dry weather flow at Sharon of 200 c.f.s., and it is expected that this will be approximately 250 c.f.s. at times of maximum temperature. The

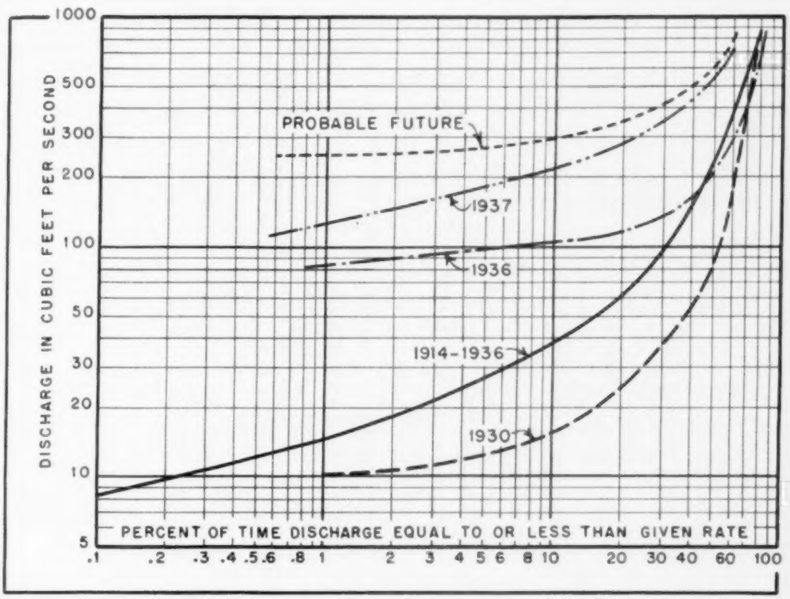

FIG. 2. DISCHARGE OF SHENANGO RIVER AT SHARON, PA.

curves in fig. 2 show the daily stream discharge data at Sharon, past and probable future.

The mean monthly discharges of the Shenango River at Sharon from 1928 to 1938, as taken from the Water and Power Resources Board's reports, are shown in fig. 3. This graph shows the effect of low-flow augmentation on both dry weather stream flows and upon the alkalinities at Sharon. The operation of the reservoir with low-flow augmentation, has materially affected the character of the river water, especially from the standpoint of hardness, alkalinity, pH value, color, tastes and odors, bacterial density, and higher cost of treatment at the downstream water filtration plants.

The effect of the iron and steel production on the watershed is noted by comparing steel production rates with the corresponding alkalinity. The normal relation of the alkalinity to stream flow on the Shenango River may be noted from the Sharon alkalinity curves in fig. 3. In 1932 and 1933 when there was little industrial activity on the watershed the alkalinity increased. The normal condition is for alkalinity to be low during high flows and high during low flows. Increased industrial activity, however, causes a reduction in alkalinity and a decrease in industrial activity causes an increase in alka-

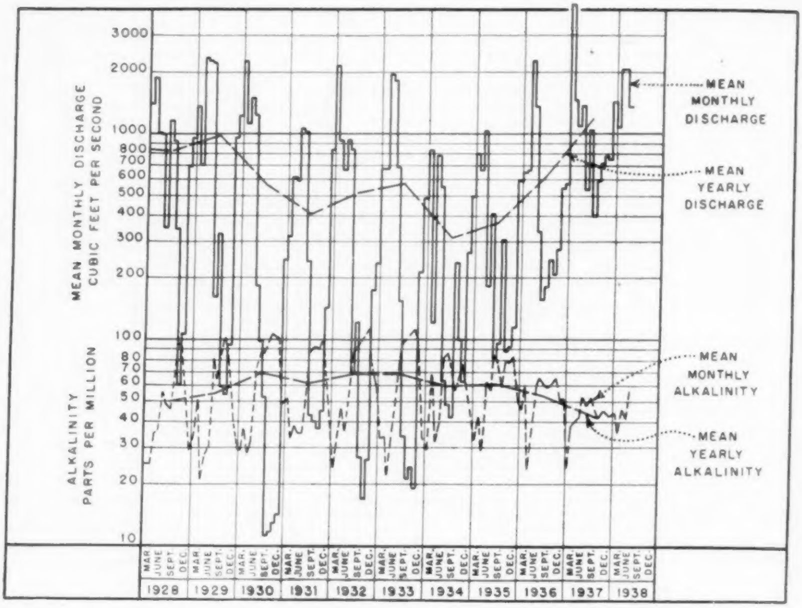

FIG. 3. DISCHARGE AND ALKALINITY OF SHENANGO RIVER AT SHARON, PA.

linity. Even the greatly increased dilution with a regulated discharge of 200 c.f.s. at Sharon, which equals roughly 25,000 pounds of additional alkalinity per day over low flows, has only partially modified this.

The natural alkalinity of the Beaver River is greatly reduced through the discharge of acid wastes from iron and steel mills, even though some of these wastes at the mills in Pennsylvania are recovered or treated, and more mills are taking steps to do this. Spent acid wastes make a double alkalinity demand upon the stream,

through both the free acid and the ferrous sulphate contained in these wastes. Assuming the 1932 alkalinity to be near the normal, calculations would indicate that the reduction in alkalinity due to these industrial wastes, is the equivalent of a daily discharge on the watershed of more than 60,000 pounds of free acid.

From the standpoint of hardness of the river water, the added summertime dilution means a substantial saving in soap costs to the downstream public water supply consumers. Results of analyses of samples of the reservoir water at the gate house outlet show it to have a hardness of 48 to 60 p.p.m. With a high rate of steel production at times of low river flows, hardnesses of 200 to 275 p.p.m. were experienced at the downstream water works plants. It is readily apparent that flow augmentation has had a material effect in reducing the hardness of the river water at times of low flow.

All of the sewage from Pennsylvania municipalities on the watershed above the Fallston Dam at New Brighton is now treated, or will be shortly. Excluding institution sewage treatment plants, a total of eighteen municipal sewage treatment plants have been constructed in Pennsylvania to date, and four small municipal plants are at present being constructed. In addition, six of the eighteen municipalities are preparing for improvements to their plants, or sewerage facilities, or both, thereby delivering their entire sewage flow to an existing plant, or completing the treatment program by constructing secondary treatment where primary treatment is now in operation. The completion of this program will result in further improving the sanitary condition of these rivers, although completely satisfactory conditions on the Beaver can be secured only through the adoption of a similar program on the Mahoning River in Ohio. Seven Ohio municipalities on the Mahoning River drainage area, having a combined population of 36,000, now have sewage treatment works.

The relationship of stream flows, or velocities of flow, and coliform organism densities of the Shenango River at New Castle before and during the completion of the sewage treatment program, is shown in fig. 4. It will be noted that, by increasing the low stream flows at Sharon to 200 or 250 c.f.s. through the operation of the reservoir, there would be a materially increased bacterial loading on the downstream water works plants, unless adequate sewage treatment were provided. This graph shows the relationship of the mean monthly stream flows at Sharon to the mean monthly coliform organism den-

sities at New Castle. An increase in mean monthly dry weather stream flow of from 50 to 250 c.f.s. at Sharon means an increase in coliform density at New Castle from about 200 to 6,000 per 100 c.c. The operation of the dam has little or no effect on changing the downstream bacterial loadings during the months of higher stream flows. Prior to completing the sewage treatment program, monthly

TABLE 1

Mahoning River Results

MONTH	TEMPERATURE			pH			ALKALINITY			Fe		CONFIRM COLIFORM INDEX PER 100 C.C.	TIME ODOR* INTENSITY 3 OR BETTER	MEAN MONTHLY DISCHARGE, YOUNGSTOWN	NUMBER OF DAILY SAMPLES
	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Maximum	Minimum				
1936													*per cent*	*c.f.s.*	
July	77	88	76	7.2	7.6	6.4	28	44	8	11	0.1	1,800	0	110	21
August	82	87	77	7.1	7.4	6.3	36	54	12	0.3	0.1	2,890	11	146	26
September	79	85	69	6.7	7.2	5.8	26	48	8	16	0.1	870	4	169	25
October	74	85	63	6.9	7.4	5.7	35	62	6	12.5	0.2	2,030	7	285	27
November	55	74	48	6.9	7.7	6.0	38	71	9	12.5	0.5	87,500	40	181	25
December	55	62	45	6.4	7.4	6.0	19	60	4	22	7.5	14,720	31	380	26
1937															
January	45	60	38	7.1	7.6	6.9	32	60	20	200	2.5	85,500	69	6,055	26
February	49	61	43	6.6	7.1	6.0	24	37	7	25	1.5	56,090	48	867	23
March	53	64	43	6.7	7.1	6.3	26	60	10	60	1.5	49,300	45	1,161	27
April	62	73	52	6.7	7.2	6.0	26	50	9	15	1.0	47,400	68	1,554	26
May	75	86	71	7.1	7.5	6.6	39	68	22	12.5	1.0	26,100	4	886	25
June	79	85	75	7.3	7.8	7.1	56	71	39	8.8	1.5	34,000	40	948	25
July	85	92	79	7.2	7.8	6.7	44	66	21	10	1.6	45,200	43	945	28
August	89	96	85	7.4	7.8	6.2	54	70	12	3.0	0.2	2,870	16	250	25
September	79	95	71	7.2	7.8	6.5	44	76	13	6.2	0.1	26,980	0	519	25
October	90	85	59	7.1	7.6	5.7	44	62	7	7.5	0.1	22,140	31	317	26
November	57	65	47	7.4	8.0	6.7	58	80	36	8.7	0.2	15,100	8	262	26
December	42	53	37	7.2	7.8	6.5	48	75	16	20.0	2.0	75,700	12	970	26
1938															
January	41	51	35	7.4	7.8	7.1	51	70	38	4.5	2.0	115,000	0	811	24
February	43	51	38	7.3	7.4	6.9	40	62	33	3.5	1.6	93,200	0	870	22
March	46	58	37	7.2	7.8	6.9	36	56	29	6.0	3.7	112,000	8	2,730	27
April	57	72	43	6.9	7.6	6.8	41	78	18	2.5	2.0	91,190	4	2,020	26
May	67	75	62	7.6	7.9	7.3	66	97	42	3.5	0.2	22,200	12	1,110	25
June	75	83	70	7.6	8.4	7.2	71	91	52	1.6	0.4	19,000	0	378	27
July	82	90	75	7.7	8.4	7.4	80	108	58	0.3	0.1	7,180	0		25

* Odor refers to chemical as phenol, tar, oily, or medicinal.

coliform loadings of 20,000 to 35,000 per 100 c.c. were experienced at these times. The Beaver River water works are now operating with a raw water nearly equally polluted, due principally to the effect of the Mahoning on this stream. The Beaver River has been affected to a lesser extent than the Shenango River through increased bacterial loadings resulting from increased summertime flows. The treatment of sewage is essential where water filtration plants are operating under such high bacterial loadings.

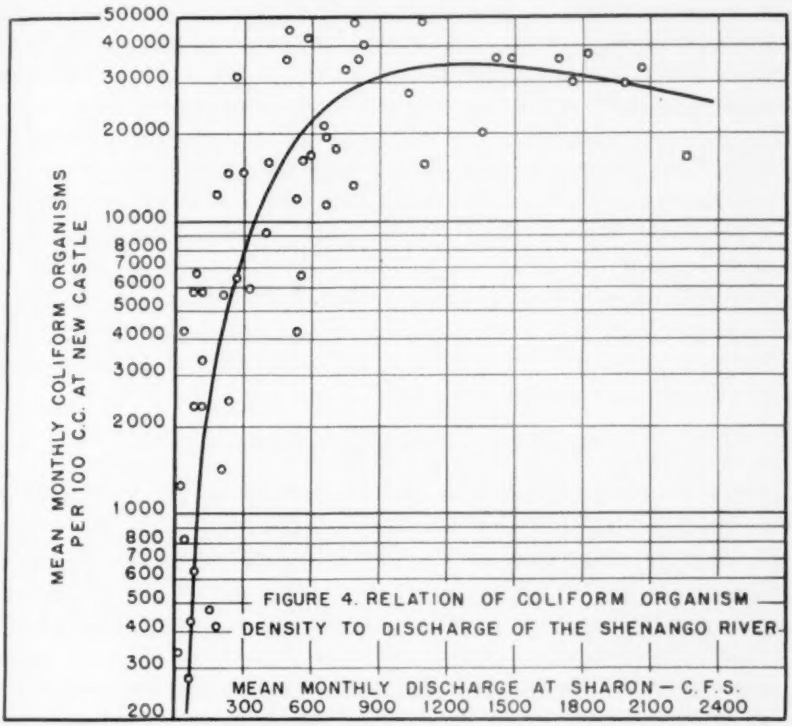

FIG. 4

A monthly summary of the results of samples of the Mahoning River as secured in Pennsylvania at a point about 20 miles below Youngstown, but above Pennsylvania influences on the stream, is given in table 1. The inhibiting effect of the acid pollution in the Youngstown area, combined with low stream flows and low velocities of flow, is noted by the marked reductions in sewage bacteria. Higher stream flows reduce the time of transit and the effects of the acid wastes; they likewise produce a scouring effect on the stream

bed, with the result that daily coliform densities of at least 200,000 per 100 c.c. are frequently observed in this stream above its confluence with the Shenango. Also, a decreasing of industrial activity as is being presently experienced, with reduction in spent acid discharge, is readily apparent through increased numbers of sewage bacteria. Likewise, it will be seen that the per cent of the time that taste and odor producing substances are present in the samples is related to industrial activity and stream flow. The odors refer to hot odors of an intensity equal to or greater than "distinct," the odors being classified as chemical, such as phenol, creosote, tar or oil. While it will be noted that taste and odor materials are too frequently present in the river in Pennsylvania, it is usually only at times of lower water temperatures and heavy rainfalls with high run-offs from the areas around the coke-quenching facilities at the by-product plants in Youngstown, that the worst taste and odor conditions are experienced at the Beaver River water plants. The results recorded in table 1 under iron (Fe) are in most cases either the maximum or minimum for weekly composites collected during the month. In a few cases the results given are for a single day's sample, taken at or during a quick rise in the river, to show the effect of scouring upon previously precipitated iron salts.

Results from Pymatuning Reservoir

Limited results during the winter of 1936 at the same station showed 8.0 to 12.1 p.p.m. dissolved oxygen, equivalent to 60.9 to 91.7 per cent saturation. Summer results for the past several years, showed 1.0 to 8.0 p.p.m. dissolved oxygen, equivalent to 11.2 to 100.2 per cent saturation, with .6 to 5.1 p.p.m. 5-day biochemical oxygen demand.

It was to be expected that the construction of the dam, by flooding large areas of swamp land with large releases of water during warm months, and especially during the early years of operation, would have a marked effect on the Shenango and Beaver Rivers. Results of analyses of Pymatuning Reservoir water, and of the Shenango and Beaver Rivers during the summer months, since the placing of the reservoir in operation, have borne out earlier expectations. At the end of three years operation, Linesville Lake, which is a small, constant level, separate part of the reservoir, covering considerable swamp land, contains low amounts of dissolved oxygen in the warmest months, and has a color averaging from 75 to 150

p.p.m., with a 5-day biochemical oxygen demand of 1.2 to 9.0 p.p.m. at its outlet. Three years of operation of the main reservoir have produced no improvement in the quality of the water released, possibly due to the very large reservoir capacity as compared to its drainage area and the rates of withdrawal. The color of the water withdrawn has ranged generally between 45 and 80 p.p.m.

Previous to placing the reservoir in operation, peak colors up to 250 p.p.m. or more would be experienced at the downstream water works with the first run-off from the swamp areas and with low colors, ordinarily 20 to 30 p.p.m., for sustained low flows. The low-flow augmentation has resulted in a materially increased color during sustained low flows, with a continuation of substantial color peaks at times of first run-off, due to the effects of the dam in regulating and controlling the flow from the main swamp, thereby permitting the effects of the tributary swamps to be felt to a greater degree. The dissolved oxygen of the lake water at the gatehouse has varied, during the summer months of 1935-36-37, from 30 to 88 per cent saturation, with a 5-day biochemical oxygen demand of 1.4 to 5.9 p.p.m. Because of the relative shallowness of the lake, there is little difference between the quality of the top and bottom waters.

For the purposes of study, the river system has been divided into five zones: the Reservoir; the Shenango River between the dam and Sharpsville; between Sharpsville and the confluence of the Shenango and the Mahoning Rivers; the Beaver River from the confluence of these streams to the Fallston dam at New Brighton; and from this dam to the confluence of the river with the Ohio. The effect of the Pymatuning water on the river can best be noted in the first zone, which is the zone of the least artificial pollution and which receives only the settled and chlorinated sewage from Jamestown and Greenville whose combined population is 9,500. Table 2 summarizes the results of the stream surveys on this portion of the stream for the summer months in 1932, 1935, 1936, and 1937.

The 1932 results show the effects of natural processes of oxidation operating on the unregulated low stream flows by breaking down the organic content of the water and increasing its dissolved oxygen content, as the stream slowly flowed the 35 miles between the site of the proposed dam and Sharpsville. The subsequent results show the changed character of the water and the effect of the decomposing vegetation and dissolved organic matter in producing a materially

increased oxygen demand. The increased stream flows with low-flow augmentation reduce materially the time of flow, thereby affecting purification and oxidation of the dissolved organic materials. The less favorable oxygen balance at Sharpsville with low-flow augmentation in comparison with the year of unregulated flows

TABLE 2

Summary Shenango River Sanitary Survey, Upper Zone

YEAR AND STATION	TEMPERATURE	DISSOLVED OXYGEN	SATURATION	BIOCHEMICAL OXYGEN DEMAND	MEAN RIVER DISCHARGE AT SHARON	MEAN PYMATUNING DAM RELEASE	DISTANCE FROM DAM	DRAINAGE AREA	NUMBER OF DETERMINATIONS
1932	°C.	p.p.m.	per cent	p.p.m.	c.f.s.	c.f.s.	miles	sq. mi.	
Jamestown	19.5	6.72	73.2	1.49			2	170	
Greenville*	19.9	7.35	79.6	0.88			7	190	
Clarksville	20.7	7.73	83.8	1.09			28	405	
Sharpsville	21.6	8.30	91.5	0.85	47	0	37	600	11
1935									
Jamestown	19.4	7.38	78.54	2.20					
Greenville	20.0	8.42	90.91	2.88					
Clarksville	20.5	9.32	102.70	2.15					
Sharpsville	20.5	8.64	97.22	1.83	214	34†			5
1936									
Jamestown	19.2	8.09	85.2	3.09					
Greenville	18.5	8.05	83.8	3.48					
Clarksville	19.0	8.61	90.2	3.50					
Sharpsville	19.7	8.74	93.6	2.61	262	130			6
1937									
Jamestown	22.7	6.55	75.0	2.95					
Greenville	22.6	6.60	82.9	3.13					
Clarksville	23.3	7.66	88.7	4.33					
Sharpsville	24.1	8.25	96.7	3.66	343	218			4

* Station is 2 miles above Greenville.

† Dam only partly full.

has limited, more than was expected, the assimilating capacity of the stream at that point during the early years of the dam's operation.

From the taste and odor standpoint, the river system can logically be divided into two zones, the Shenango River and the Beaver River zones respectively. The Shenango River water filtration plant

problems have been related mostly to organic decomposition taste and odor problems, occasionally to algae, but rarely to industrial wastes or combinations of these. The Beaver River problem has been a combination of similar tastes and odors as experienced on the Shenango and of phenols or similar materials originating from the Mahoning River in the Youngstown area, plus an occasional upstream Pennsylvania industrial waste taste or odor. While the by-produce coke works in the Youngstown area are provided with coke-quenching or similar facilities, intermittent objectionable tastes and odors have continued at the downstream water works, particularly during the cold months which are the months of highest stream flows and lowest water temperatures. These periods, as before mentioned, are related to industrial activity, and seemingly to run-offs at times of heavy rainfall on the area around the coke-quenching facilities.

Since the placing of the Pymatuning Reservoir in full service in 1936, the Shenango and also the Beaver River water works, to a lesser degree, have experienced greatly increased difficulty from algae and related taste and odor control. While algae and decomposition tastes represent a substantial problem, the major problem in this respect on the Beaver River continues to be the usually infrequent winter phenolic tastes that are little affected by the reservoir's operation. All of the water works plants employ pre-chlorination, ammonia, and activated carbon treatments as required, and the majority of the plants use aeration as an additional facility for taste and odor control. With the exception of the time when phenols are present in objectionable amounts, the present taste and odor facilities produce with few exceptions, a satisfactory finished water.

Chemical Costs Increase

Many waters have a distinctive taste, which possibly should be classified as a flavor, which one not accustomed to the water supply will observe as a slight after-taste. The re-use of surface streams for industrial cooling and processing purposes, combined with the discharge of spent acid wastes or coal mine drainage, or both, in amounts, produces what is termed by some as a "musty steel mill flavor" that persists in the finished water, especially at higher water temperatures, and is slightly noticeable yet not objectionable to the unaccustomed consumer. This condition has been noted at times in the Beaver River water supplies as well as in other similarly situated

water supplies. The added summertime dilution with the reservoir in operation has resulted in improvement in this respect.

All of the downstream water filtration plants have noted a materially increased chemical cost since the placing of the reservoir in operation. The increased chemical cost has varied at the different plants from one-third to almost two-thirds more than former costs. The changed character of the water requires higher chemical dosages, especially of coagulant, chlorine, and activated carbon. With an improvement in the water of the reservoir with continued use, it is expected that a better quality of water will be released, with resultant reduction in chemical cost.

Because of the nature of the drainage area, density of population, development and concentration of the predominating industrial activity with relation to the size of the drainage area, it was to be expected that, up until recent years, a raw water of widely fluctuating character would be obtained at the various water filtration plants on this river system. The drainage from the swamps on the watershed affected at times, and markedly so, the quality of the river water from the standpoint of color, tastes and odors, and chemical treatment. The sewage during low flows in some cases produced local abatement problems and during higher stream flows, which usually occur during the colder months, caused the raw water for the down stream water filtration plants to be highly polluted.

Taste and Odor Problem Intensified

The use of the river water for cooling purposes and the discharge of industrial wastes affected the temperature and the quality of the water at certain times, from the standpoint of turbidity by the iron in suspension or solution, and affected the hardness, alkalinity and pH because of the action of the acids and iron salts on the river water. At certain times, objectionable taste and odor conditions are experienced as the result of wastes reaching the river from the by-product plants; likewise, wastes from these or related industries, combined possibly with the swamp run-off, have materially increased the chlorine demand of the water, which has intensified the problem of taste and odor control, especially where chlorination is practiced as a necessary part of the filtration process. These varying factors, in combination at times, indicate the problem of pollution control and the operation problems of the downstream water purification plants prior and even following the placing of the reservoir in service.

The State Health Department has instituted a pollution control program on the Pennsylvania drainage area of these streams as a means of substantially improving the sanitary condition of the rivers and their tributaries. This program has been developed with the expectation that the Pymatuning Reservoir would be constructed and the low stream flows at Sharon would be increased to a minimum of 200 to 250 c.f.s. The dam has been constructed and the reservoir placed in service, and the control program for sewage treatment is nearing completion. Likewise, substantial progress has or will be effected in the treatment of industrial wastes.

The reservoir created by the dam covers a large, swampy area, and the water released for low-flow augmentation has been markedly affected, especially during the warm months, by the decomposition of the organic materials on the reservoir bottom. This water, when released, has had an effect on the entire river system below the dam. The principal benefit thus far obtained from the dam has been the increased capacity of the river for assimilating the treated and the partially treated sewage and industrial wastes, which condition, combined with the stream pollution control program, has resulted in greatly smoothing out the fluctuations in the chemical quality and has reduced the bacterial densities of the river water in comparison to what these conditions were before these activities and prior to the placing of the reservoir in service. This benefit, from the water filtration standpoint, has been secured through a greatly increased cost of purification.

The next step in this program is an improvement in the quality of the Mahoning River water. The quality of the reservoir water will improve over the years, and with this improvement and the completion of the control program, added benefits will be obtained, affecting all of the uses and users of the rivers below. This drainage area problem illustrates the fact that the greater and more concentrated the pollution, with relation to the size of the stream, the more difficult becomes the problem of pollution control, as well as the operation of the downstream filtration plants; and further emphasizes the need to give careful consideration to downstream water works where flow augmentation is to be practiced. It likewise emphasizes the fact that if taste and odor problems, occasioned by the discharge or admission of objectionable wastes to our streams, are to be satisfactorily solved, these wastes must not be allowed to reach the streams that serve as the source of the public water supply.

Flood Control and Water Supplies

By D. D. Rait

THE principal function of a flood control reservoir is to store or conserve the water at times of excessive run-off, and so release it during the intervening period that the harmful effects of floods will be avoided. If storage for other purposes can be developed in the same reservoir without conflict, the field of usefulness may be materially increased.

The Flood Control Act approved June 22, 1936, under Section 5, authorized the construction of reservoirs for the Allegheny-Monongahela Basin for the protection of Pittsburgh and the reduction of flood heights in the Ohio Valley generally. The project comprises 9 flood control reservoirs as follows: the Tionesta and Crooked Creek reservoirs, now under construction; the Redbank, Mahoning and French Creek reservoirs, all tributary to the Allegheny River; the Conemaugh River and Loyalhanna Creek reservoirs, tributary to the Kiskiminitas River and, in turn, to the lower Allegheny River; the Allegheny River reservoir, on the main stream; and the West Fork River reservoir, tributary to the Monongahela River. The Tygart River Reservoir, on the Tygart River, a tributary to the Monongahela River has been completed and placed in operation. These reservoirs as well as other locations pertinent to the project are shown in fig. 1.

The required physical characteristics of the project reservoirs, such as location, type, capacity, etc., have been determined through detailed studies of the project as 9 separate units considered individually and collectively. The combined gross capacity of the 9 authorized reservoirs is 2,140,000 acre-feet. If it were possible without conflict with flood control, and I believe it is, to conserve a part of

A paper presented at the Central States Section meeting at Wheeling, West Virginia, August 17, 1938, by D. D. Rait, Associate Engineer, Corps of Engineers, U. S. Army, Pittsburgh, Pa.

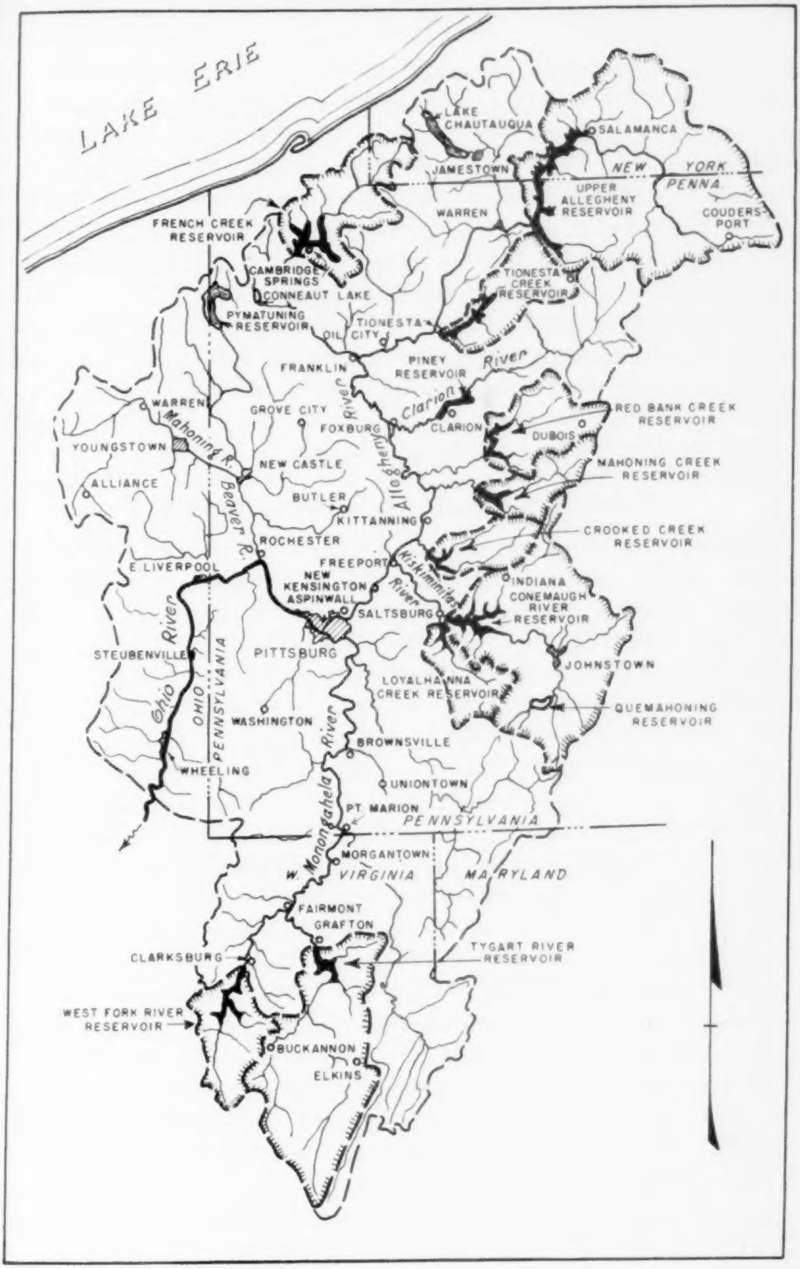

Fig. 1. Proposed Flood Control Plan, Pittsburgh District

the capacity in each reservoir, for the retention of a portion of the spring run-off, it would be of tremendous value, especially in this particular area, whether it be used as regular discharge over limited periods according to the demands of power production or as more variable discharge dictated by changing adverse downstream conditions. Water works operations are affected by these variable adverse conditions attendant upon low flow, heavy pollutional loads, or temporary excessive pollution due to local flush-outs.

The relationship of flood control projects and control of water quality in streams may best be shown by a specific study:

The polluting substances which are being deposited directly or indirectly into the waters of this district may be divided into two general classes: domestic wastes and industrial wastes.

Domestic Wastes Discharged into Streams

Domestic wastes are discharged into the streams from practically all communities situated on or near the Ohio River and its tributaries. In a great majority of cases, these wastes are discharged in a raw or untreated state directly through outfall sewers. There are 79 sewered communities, each having a population of 5,000, or more, located on the main rivers of the upper Ohio system, or close enough to them, to result in the pollution of these rivers. Eighteen, with a total population of 377,500, discharge into the Allegheny River below the site of the proposed reservoir; 26, with a population of 593,500, into the Monongahela River; and 35, with a population of 653,800, into the upper Ohio River. It is understood that orders to cease or abate the discharge of the sewage into these streams have been given to practically all the communities which are located in Pennsylvania, by the State Department of Public Health, under the new Pennsylvania Pollution Act No. 394. The States of New York, Maryland, West Virginia and Ohio have also enacted certain legislation with a view to the abatement of pollution by sewage.

Wastes resulting from industrial processes may consist of almost any acids, alkalies, salts or organic matter. These industrial wastes find their way into the waterways directly from industrial sewers, indirectly through municipal sewer systems, or by natural surface drainage. The majority of industrial plants are located directly on or near the streams. The principal industries which are the source of the more injurious polluting substances are as follows: coal mines and washeries, coal distilleries, metallurgical, pickling, cleaning and

plating plants, pulp and paper mills, tanneries, canneries, textile mills, oil fields and refineries, meat packing establishments, chemical plants, distilleries and breweries and dairies.

Classification of industrial effluents varies with the point of view. One of the best classifications considers them as follows:

1. Wastes of high organic content, similar to domestic sewage but stronger, subject to biological action. These would include distillery, brewery, starch, sugar, milk, and similar wastes.

2. Wastes rich in organic matter but not so putrescible. In this class would fall wool washings, pulp and some classes of paper, dyeing, printing wastes, etc.

3. Organic substances not readily putrescible but poisonous—such as gas and ammonia liquors, tar and tar products.

4. Inorganic wastes, such as mine drainage, acid pickling liquors, soda and potash wastes, salt water from oil wells, etc.

5. Poisonous substances such as arsenic salts, sulfuretted hydrogen and other toxic substances.

Acid wastes predominate especially in the lower part of the Allegheny, in the Monongahela and the upper Ohio River basins. Acid wastes of this type may be neutralized. There are some salt water wastes and these can be removed only by evaporation. The polluting substances in the basin are restricted, with a few exceptions, principally to sewage and acid wastes. Their harmful effects can be reduced or eliminated by dilution.

This proposed flood control reservoir, located on the upper Allegheny River, will at the elevation studied, have a gross capacity of 1,125,000 acre-feet. The volume of storage to be provided for pollution abatement, by dilution, has been assumed to be 520,000 acre-feet. This storage would be impounded annually from inflow over 500 second-feet during April and May and released as required during the period, June to November, inclusive. This volume of storage represents the difference between the gross storage capacity, 1,125,000 acre-feet, and the sum of the permanent storage, 20,000 acre-feet, and the summer flood control capacity of 585,000 acre-feet. This dilution storage of 520,000 acre-feet represents the reservoir capacity available without conflict with flood control and is the basis for the supply to be used for the abatement of the polluting substances.

The water to be impounded for dilution purposes will be collected from a drainage area of 2,190 sq.mi. above the site of the proposed dam. The total population above the dam site is approximately

103,000 people, averaging less than 50 per sq.mi. The population is well distributed over the watershed and there is a tendency toward natural purification of sewage from the main sources before it reaches the site of the dam.

Possibilities of pollution by mine drainage from sources above the dam are negligible. Seventy-five per cent of the area is north of the coal measures in the basin. There are a few industries in the basin of importance in relation to pollution. The distribution and character of their wastes, however, are such that there should be no discernible effect on the quality of the water in the reservoir.

Some years ago, a pollution survey was conducted from the source of the Allegheny River to a point below the proposed site of the dam. Deductions based on the results of analyses of daily samples collected over a period of more than a year from the Allegheny River at a point a few miles below the proposed site of the dam indicate that the water in the reservoir will have approximately the following characteristics: The turbidity should be low; the hydrogen-ion concentration about 7.2; the organic nitrogen should be very low; the water should be relatively soft with a total hardness of about 50 to 55 parts per million; and the alkalinity about 40 p.p.m. or less. In other words the storage should be an excellent diluting water for the reduction of organic demand and hardness and for the neutralization of free mineral acids or acid salts.

Effect of Tributary Pollution on Purification

In the course of the Allegheny River, downstream from the proposed dam site, oil wastes, the organic load of the Clarion River, a tributary, the mineral and acid load of the Kiskiminitas River and other similar tributaries have been definitely proven to affect the character of the water at various water purification plants in the metropolitan Pittsburgh district. The character of these wastes and their proximity to the Lower Allegheny Valley indicate that treatment modifying their characteristics would be beneficial to the water purification plants.

The Clarion River contributes a heavy organic load to the Allegheny River below Foxburg. The organic content is due, to a slight extent, to the character of the vegetation on the watershed but principally to wastes from pulp and paper mills and tanneries near the headwaters. Every year during the past few years, water purification plants on the Allegheny River as far downstream as Pittsburgh

have had taste and odor troubles traceable to these sources of pollution. The operation of Piney Reservoir may aggravate these troubles. Organic wastes collect in the reservoir during periods of low inflow. Evaporation concentrates the wastes in the reservoir, partial decomposition occurs and the anaerobic action aids in the formation of toxic, taste and odor producing substances from the fragments of organic matter which settle in the bottom of the pool. At times the Clarion River water contains a larger amount of organic matter than can be assimilated by the Allegheny River. The result is disturbances at downstream filter plants resulting in taste, odor, color, etc., in the treated water.

Endeavor to eliminate the Clarion River pollution has been made for a long time. However, the problems appear to be so complex and deep-seated that even under the new Pennsylvania legislation (Act No. 394), it may take years to eliminate the pollution at its sources on the headwaters of the Clarion River.

Kiskiminitas River Is Main Cause of Acidity

The Kiskiminitas River is a tributary of high acid content. The greater part of the acidity is due to acid mine drainage and a smaller part, to waste pickling liquors from metallurgical plants. The Kiskiminitas River is the main cause of the acidity, hardness and corrosive action of the water of the lower Allegheny and it has a marked effect on the upper Ohio River. Intensive studies of this stream, covering a period of more than two years, show that practically every time soda ash is used at the Pittsburgh municipal filtration plant, it corresponds with a prior increased acid condition of the Kiskiminitas River. Studies extending over a number of years show only one or two cases of neutral or alkaline water in this stream and these cases corresponded to periods of high discharge. The acidity in the stream varies. The maximum acidity at the mouth during two short periods was 1,020 and 1,000 p.p.m., respectively. The fluctuating character of the acid discharge from this stream is a constant source of worry to operators of water works along the lower Allegheny River.

The Kiskiminitas River is also the chief source of mineral pollution of the lower Allegheny River. The water is hard and contributes to the manganese content of the main stream. At times there is complete mixing with the waters of the main stream, but there is often a tendency to cling to the left bank of the Allegheny River and

frequently there is not a complete mixture until after the flow reaches New Kensington.

The acidity and hardness of the stream place a definite economic burden on users of the river water, the influence at times extending some distance down the Ohio River. The abruptness of the changes in the acidity constitutes a secondary health menace to downstream filtration plants, especially those of the rapid sand type, through rapid changes of the hydrogen-ion concentration in the raw water and consequent loss of floc. The quality of the discharge of the Kiskiminitas River may not improve for many years and then only partially.

The Pennsylvania Pollution Act No. 394 is designed to eliminate the acid discharges from metallurgical plants. Mine sealing is restricted to abandoned mines; it has been sporadic in character and designed principally to furnish work for the unemployed, and has not as yet become a stream purification measure of wide application. Conceding the possibilities of mine sealing and treatment of industrial wastes in the basin, some improvement may be expected. There is, however, nothing in Act No. 394 which prohibits new mines from being opened indiscriminately. Taking all factors into consideration, it would appear that the tendency towards reduction of acid conditions in this stream might result only in a temporary stay in the trend towards higher acidity.

Allegheny River Becoming an Acid Stream

The lower Allegheny River at Pool No. 2 (Aspinwall, Pa.) was, in its natural state, an alkaline stream. It has gradually approached an acid condition until at the present time it is frequently acid for considerable periods. Waste acid pickling liquors tend to increase the acidity but are of minor consideration compared with mine drainage. As shown in figure 2, the trend of decrease in the alkalinity has been from 20 p.p.m. in 1909 to 3 p.p.m. in 1933. If this trend continues, the lower Allegheny River will eventually become an acid stream most of the time with adverse effect upon the upper Ohio River. The sudden fluctuations and peak loads of acidity in the Allegheny River at Aspinwall place a heavy economic burden on the Pittsburgh municipal filtration plant and others near-by. There is also a distinct element of health menace. If these troubles could be removed, it would be of widespread benefit to the water consumers dependent upon this source of supply.

The navigation dams in the river and the river traffic tend to keep the oxygen content of the water up. Daily determinations of dissolved oxygen on this reach during 1937 showed 86 per cent saturation as the lowest for the year. It is seldom that the saturation is less than 88 to 90 per cent and at times there is a supersaturation, as high as 104 per cent. Biochemical oxygen demand over a number of months of an earlier period did not show an abnormally high figure. The hardness is increasing. The rapid increase during the last ten years definitely forecasts further and more dangerous conditions of hardness of the water from the lower Allegheny and upper Ohio Rivers. Consumers will be forced either to seek other sources of supply or install softening plants.

The Monongahela River is an acid stream except for a few times each year during flood stages when it is slightly alkaline for short periods only. The river is heavily polluted with municipal sewage and industrial acid wastes particularly in the metropolitan Pittsburgh area in addition to the large amount of acid mine drainage which enters throughout the entire length of the river. The proximity and the diversity of the sources of pollution of the lower Monongahela River render it difficult to make correct deductions from analyses which have been made at a few isolated stations. According to a series of tests made in September, 1932 at a point 6 miles upstream from the mouth, the dissolved oxygen ranged from 3.2 to 7.4 p.p.m. The minimum amount indicates why this stream can not support aquatic life. The biochemical oxygen demand varied up to a maximum of 1.3 p.p.m. and the methyl orange acidity from 5.0 to 3.5 p.p.m. The bacterial counts during the same period were relatively low, attributed by some to the lethal or inhibitory effect of the acids present. The results indicate that the Monongahela River has a definite acid and organic polluting effect on the Ohio River.

The character of the Ohio River water at the head of the river is complicated by local conditions. Industrial and municipal pollution reaches the river in such manner that there is no thorough mixture until some distance below Pittsburgh. Local tests carried on at short intervals for a two-day period showed both vertical and horizontal stratification and, unless a large number of cross-sectional and depth samples is taken, it is difficult to draw conclusions as to the character of the water of the Ohio River above the vicinity of the mouth of the Beaver River. Samples taken at a point on the Ohio River just above the mouth of the Beaver for the period September

to December, 1932, indicated that the Ohio River had a fairly high oxygen content, the per cent saturation varied (it was usually about 85 per cent) and the biochemical oxygen demand was low. The highest value during the period of testing was 2.7 p.p.m. at a time corresponding to the highest turbidity. The alkalinity during the period varied from 0.3 to 22.3 p.p.m. with an average of approximately 4 p.p.m. during low water conditions (methyl orange indicator). This alkalinity is near the danger point and the stream will become acid if the trend for the past few years continues.

The issue of "Public Health Reports" of January 28, 1938 (U. S. Public Health Service) states, "It can, however, be stated that conditions in the future in this area should tend to become more critical rather than to improve."

Peak Pollution Taxes Present Plants

The report states further: "When increases in river discharge take place at Pittsburgh, following periods of pool stage, to the extent that scouring velocities are produced, the sludge deposited in the pools is flushed downstream, and, because of greater dilution of the acids, less inhibitive action results and more normal biological action takes place in the stream. As a consequence, a series of highly concentrated waves of organic and bacterial pollution passes downstream to affect the operation of water treatment plants below, imposing upon them for varying periods of time a pollution load far in excess of that for which they were designed. At such times a slip in operating technique might easily result in the appearance of water-borne diseases within the community. Following the flushing-out process, increasing river velocities bring pollution rapidly from upstream sources to the water works intakes before agencies of natural stream purification have time to operate, so that in the Ohio River the maximum degree of raw water pollution at water works intakes does not occur at times of minimum run-off but during periods when the discharge is considerably above the minimum flow."

The Beaver River is an alkaline stream with a relatively high bacterial load. This is probably due to the heavy pollution of a relatively small stream. The river is perhaps too small to produce more than a local change in the character of the Ohio River water. Small local changes in alkalinity may be of a permanent nature but the increase in organic pollution may be eliminated by the ordinary process of self-purification.

The following is quoted from the January 28, 1938 issue of "Public Health Reports":

"At East Liverpool, immediately below Pittsburgh, the limit of bacterial pollution which the usual type of water filtration plant would be expected to handle satisfactorily is exceeded during about 50 per cent of the time, based on the average monthly results of bacterial determinations at the water works plant. At Steubenville, Wheeling, Marietta, and Huntington, the intensity of pollution decreases, and, in the order of the communities named, the limit of raw water pollution was exceeded about 16, 15, 12, and 1 per cent of the time, respectively."

An early unpublished report for the Pittsburgh Engineer District discusses the condition of the Ohio River water in the Wheeling area as follows: "It can be seen . . . that the lower end of the district is producing in itself sufficient pollution to destroy fish and injure boilers and that the damage to those cannot be entirely charged to the upper end of the district." There is no reason to assume that conditions have changed for the better since the report was issued; a worse condition is more probable.

As a result of investigations of the sources, types and degree of pollution of the Allegheny-Upper Ohio River, it is apparent that the pollution is of long-standing, deep-seated and may even increase despite legal attempts to correct the situation. A large part of the area is concerned with coal mining and metallurgical industries. Liquid wastes result and find their way into the streams. Acid mine waste is the principal type of pollution. Elimination of pollution at individual sources is difficult and expensive. Some progress is being made by sewage disposal, treatment of industrial wastes and sealing of abandoned mines. Further progress is to be expected. However, the region will and should continue as a principal source of coal production with hundreds of active mines. Pollution will continue to be a problem for a long time to come.

To sum up the factors discussed thus far: A description has been given of the calculation of the capacity of the reservoir for the storage of water to be used for dilution purposes, in this case, 520,000 acre-feet. The sources of pollution have been discussed and their effect on the lower Allegheny-Upper Ohio Basin has been shown. An attempt will now be made to show the practical solution of the pollution problem in the main streams in conjunction with, or you might say as a by-product of, flood control reservoirs.

The creation of storage on the headwaters for the abatement of pollution suggests the possibilities of diluting the various pollution substances to such a degree that they will be rendered impotent. If possible, the acidity would be neutralized and the hardness materially reduced. From studies of the present and probable future composition of the water in the proposed reservoir, it was estimated that the storage in the reservoir would have an average alkalinity of 40 p.p.m. and an average hardness of 52 p.p.m. It is recognized that there will be some seasonal variation in these qualities, but it is believed that these figures represent conservative averages.

The proposed plan of operation of storage for dilution purposes contemplates the release of sufficient water from storage to neutralize the acid and dilute the mineral load of the lower Allegheny River. The increase in river discharge would furnish additional oxygen to eliminate the organic load in the upper Allegheny River and materially lessen that of the lower river with consequent benefit to the upper Ohio River. Water would be released as required to anticipate dilution demands on the lower Allegheny River particularly in relation to the Clarion River and Kiskiminitas River discharge. The amount of water released would depend primarily upon the river discharge and its chemical constituents.

Control Stations Required

In order to operate storage if provided in the Allegheny reservoir for dilution purposes, control stations to report meteorological, discharge and chemical conditions would be required at strategic points on the main stream and on principal tributaries both polluted and unpolluted. Such stations could be readily made available at the flood control dams of the authorized reservoir system for the Allegheny River tributaries, at navigation locks, principal water supply plants, and elsewhere. Data for the Clarion and Kiskiminitas Rivers would be particularly pertinent. In fact, such forecasts of discharge conditions for these tributaries are already being successfully made in relation to water works operations in the Pittsburgh area.

The junction of the Kiskiminitas River with the Allegheny River is a relatively long distance below the site of the proposed dam. Although the scheduled release of water from the reservoir would, it is expected, control the ordinary conditions of the harmful Kiskiminitas River discharge, extraordinary conditions could be effectively met by the development of pondage on Pool No. 5 above Freeport

on the Allegheny River. This would be an ideal location for the purpose because of proximity to the mouth of the Kiskiminitas River. The navigation pool has an area of about 650 acres. Dam No. 5 is provided with crest facilities for the use of 30-inch flashboards if desirable. The pondage could be released when needed by removal of flashboards to further dilute unusual Kiskiminitas River discharges. With outlets in the dam, the entire pondage above the fixed crest could be released. The necessity for release of pondage from Pool No. 5 is expected to be infrequent.

The large filtration plant of the City of Pittsburgh is located at Aspinwall on the right bank of Pool No. 2, Allegheny River, about 8 miles above the mouth. Records are available for this plant which show the daily alkalinity, hardness and other characteristics of the raw Allegheny River water over a period of 30 years. Figure 2 shows the alkalinity and hardness in monthly averages in ten-year periods. A study of these records gives an accurate picture of the present conditions, the changes and trend of change in the river water during the period. Figure 3 shows the trend toward acidity in both the Allegheny and Monongahela Rivers.

Upon review of the detailed records, the critical years of pollution were found to be 1930 and 1934, with 1932 a typical normal year, for determination of the possibilities of dilution to control alkalinity and hardness and to improve the general characteristics of the water in the lower Allegheny River. The year 1930 was found to represent low discharge and 1934, high acidity.

The volume of storage to be provided in the reservoir for pollution abatement, by dilution, has been assumed to be 520,000 acre-feet, as discussed in a previous section of this paper.

In 1930, the year of low discharge, the Allegheny River at Aspinwall was acid for 78 days. Less than 15 per cent of the dilution storage of the reservoir would have been required for complete neutralization of the acidity of the river and partial reduction of hardness. The remainder of the storage could have been available to reduce further the hardness and build reserve alkalinity to neutralize the acidity of the upper Ohio River. The regulated discharge from the reservoir would have reduced the maximum hardness (with a one-week exception) to 120 p.p.m. For the period from June 1 to November 30, inclusive, the average reduction in hardness would have been 77 p.p.m. with the greatest average monthly reduction at 135 p.p.m. during the month of September.

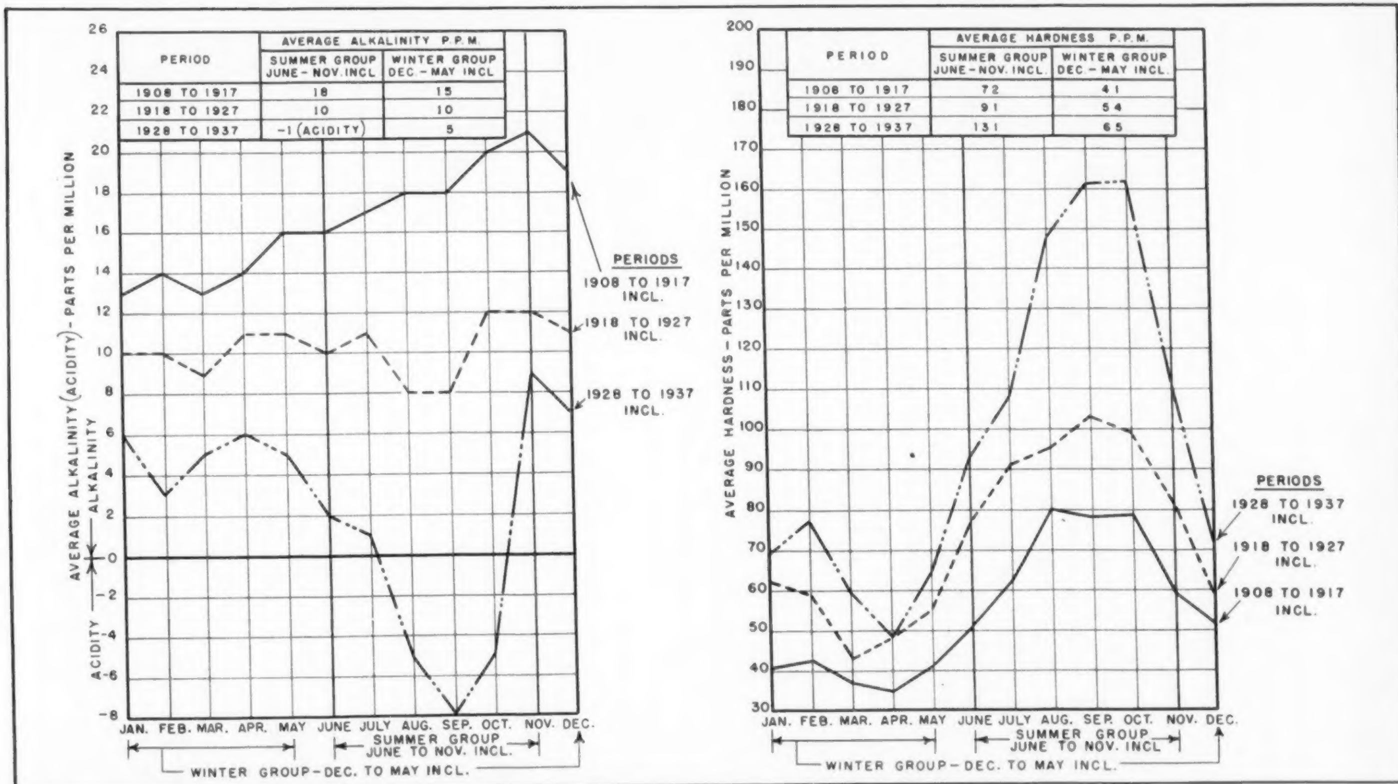

FIG. 2. ALKALINITY AND HARDNESS OF THE ALLEGHENY RIVER

Shown in monthly averages over 10-year periods; tests taken at Lock No. 2

In 1932, the year representing normal conditions, the Allegheny River at Aspinwall was acid for 77 days. To neutralize the river completely and partially reduce its hardness slightly over 15 per cent of the dilution storage of the reservoir would have been required. The regulated discharge from the reservoir would have reduced the hardness to below 115 p.p.m., an average reduction of 44 p.p.m., for the period from June 1 to November 30, with the greatest monthly reduction at 99 p.p.m. during the month of October.

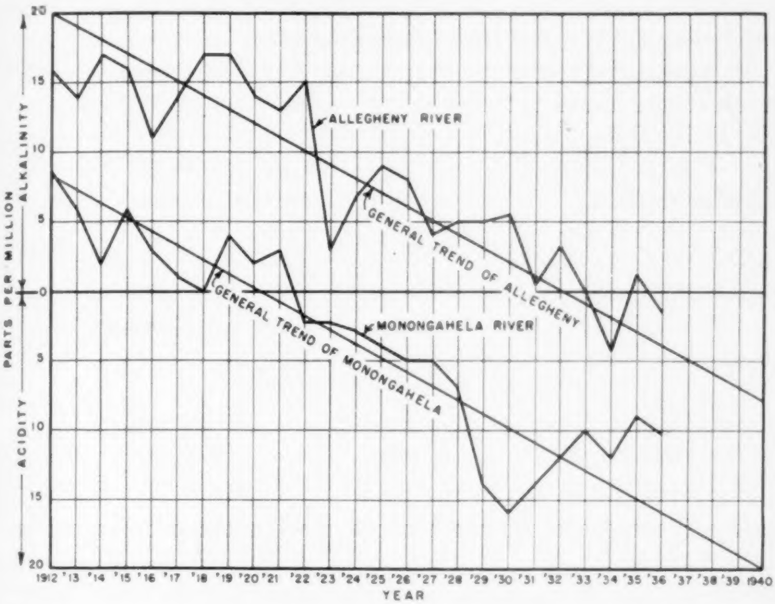

FIG. 3. TRENDS AND COMPARISON OF THE ALKALINITIES OF THE ALLEGHENY AND MONONGAHELA RIVERS

In 1934, the year of the greatest acidity of the Allegheny River at Aspinwall, the river was acid for 194 days. Even for this year, less than 85 per cent of the dilution storage would have been required to neutralize completely the acidity and partially reduce the hardness of the Allegheny River. The regulated discharge from the reservoir would have reduced the hardness (with a three-week exception) to 120 p.p.m. or less for the entire year. During these excepted three weeks, the average hardness would have been reduced from 215 to 144 p.p.m. The average reduction for the six-month period would have been 32 p.p.m. with the greatest monthly reduction at 43 p.p.m. during the month of October.

The increase in low water discharge by dilution with water from the Allegheny River reservoir is shown in table 1.

The regulated discharge from the Allegheny River reservoir would be sufficient to maintain a neutral condition on the lower Allegheny River and provide sufficient reserve for a beneficial effect on the upper Ohio River. This would be of great value both to industrial and municipal water supplies which are now forced to neutralize the water. A conservative estimate indicates that an average of 175,000,000 gallons of water is now being neutralized daily during acid periods in the area under consideration.

The regulated discharge from the reservoir during normal and low flow periods, with few exceptions of short duration, would reduce and hold the hardness of the lower Allegheny River to below 120 p.p.m., an average reduction of 51 p.p.m. during the summer seasons for the years studied. The volume of soft water from the Allegheny

TABLE 1

Minimum Weekly Average Discharge at Lock No. 2 of Allegheny River

YEAR	NATURAL	REGULATED
	second-feet	*second-feet*
1930	764	1,942
1932	950	3,087
1934	971	2,620

River with a 2 to 1 ratio of discharge to the Monongahela River would materially reduce the hardness of the upper Ohio River with the consequent beneficial effects which would extend downstream. The savings in soap consumption alone would be a decided economic benefit to 1,000,000 consumers, who use the Allegheny River as a source of domestic water supply.

The amount of oxygen carried by a stream is a factor limiting the amount of organic matter stabilized in the self-purification of the stream. The total volume of oxygen in an unpolluted stream is dependent on the flow of the stream and the temperature. During the periods of low flow, the regulated discharge from the reservoir would at least double the flow of the Allegheny River at the source of the highest organic load, and thus furnish an additional amount of oxygen equivalent to that of the Allegheny River at low flow, with beneficial effect on the upper Ohio River.

The tastes and odors due to the discharge from the Clarion and

other upstream tributaries would be materially reduced or completely overcome by dilution with the water from the reservoir. These tastes and odors are not only objectionable but have a potential health menace, through driving the consumer to the use of water which, although palatable, may be extremely dangerous due to content of pathogenic organisms.

Troubles due to manganese, which are increasing on the Allegheny and upper Ohio Rivers, would be naturally reduced or overcome by dilution, with water derived from the reservoir.

The metropolitan district of Pittsburgh is one of the most highly industrialized districts in the country and a sufficient amount of water of good quality must be available at a reasonable price for these industries. High quality water is an absolute necessity for most industrial operations. It is quite evident that any industry dependent upon high quality water would be materially benefited by a materially improved source of supply, some directly through their ability to use the softer water, but in the majority of cases, indirectly through the lessened cost of purification of the river water for manufacturing processes.

Chief Operations Reviewed

The main operations required for dilution, with water from the reservoir, would consist principally of the anticipation of pollution conditions to be abated, timing and release of water from the reservoir, and mixing of water from storage with the polluted water. Controlled outlets provided at the reservoir for release of flood water would serve the purpose of releases for dilution. An adequate system of control stations with communication for determining and timing the releases from storage would be provided. Facilities at Tygart Dam consist of slide gates and needle valves, the latter for small regulation.

Mixing of the waters would be accomplished in considerable measure by means of the eight fixed navigation dams now in operation and under construction on the lower Allegheny River. Flashboards for the crest of Dam No. 5 (just above Freeport, Pa.) were discussed under auxiliary storage possibilities. The Kiskiminitas River enters Pool No. 4 about 1,200 feet below the abutment of Dam No. 5 in the Allegheny River. To assure immediate mixing of water of Pool No. 5 quality with Kiskiminitas River discharge, it is proposed to construct a low barrier of derrick stone which would project from

the left bank of the Kiskiminitas River out into the Allegheny River. Such a facility would prevent the acid discharge of the tributary stream from following the left bank of the Allegheny River as it now does.

Thus the dilution storage capacity of the proposed reservoir will practically double the low flow of the lower Allegheny River. This amount of water of the quality of that in the reservoir will, under conditions of properly regulated flow, neutralize the harmful acid discharges of the Kiskiminitas River and have a marked beneficial effect on the upper Ohio River. It will decidedly lower the hardness of the lower Allegheny with marked good effects on the upper Ohio. The harmful effects of manganese will be lowered by the dilution factor of the additional water furnished. Taste, odor, and color troubles will be materially lessened or completely eliminated. Organic matter in general will be more rapidly oxidized by the additional oxygen furnished by the added flow and complete stabilization of these wastes will be accomplished in shorter stream length so the harmful effects will be more restricted in area. It will add to the esthetic value of the stream and furnish better recreational facilities of major importance under present social trends, probably adding new activities in that direction. There is a multiplicity of other concomitant good results. At least 1 per cent of the total population of the United States and its territories will be beneficially affected by the proposed delivery of the added amount of good water to this district at times of greatest need.

Industrial Uses of Ohio River Water

By R. B. Smith

TO AN industrial man the Ohio River means several things. For one thing, it offers a splendid means of low cost transportation. The huge tonnages of coal, iron, scrap materials and finished steel products which are transported on the river bear witness to the dependence of industry upon this natural resource. For many years the Federal Government has recognized this feature and has so improved the river by locks and dams that it is available for transportation purposes even during periods of lowest water. Wheeling Steel Corporation alone transported 1,572,000 tons by river in 1937. Some other mills moved much greater tonnages during this period.

A second and probably most important service which the river renders industry is an abundant supply of process water. Few people realize the enormous quantities of water used in industry. Wheeling Steel Corporation mills at Steubenville require 100 tons of water to make each ton of finished steel. At Portsmouth Works where the corporation manufactures its own electric power 270 tons of water are required per ton of steel. It is not customary to speak of water in terms of tons but it gives a clear picture for comparative purposes.

The combined daily requirements of Wheeling Steel plants along the Ohio River, under normal operating conditions, is approximately 154 million gallons per day. The Steubenville mills use more than twelve times as much water as the City of Steubenville, five times as much as the average daily requirements of the City of Wheeling, or more than three and one-half times the daily consumption of Steubenville and Wheeling combined. Yorkville Works uses about the same amount as the City of Steubenville. Benwood Works uses about the same amount as the City of Wheeling. Portsmouth

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A paper presented at the Central States Section meeting at Wheeling, West Virginia, August 17, 1938, by R. B. Smith, Engineer, Wheeling Steel Company, Wheeling, W. Va.

Works, under normal operating conditions, uses about 80 million gallons or sixteen times the daily average of the City of Portsmouth. Ninety-three per cent of the water pumped at these plants is used for cooling purposes; 2 per cent for boiler feed water; and the remainder for processing and sanitary purposes. Wheeling Steel is only one of many industries along the river, some of which use a great deal more water.

The total amount of water pumped for industrial purposes must be expressed in billions of gallons per day. It would be impossible to manufacture iron and steel on a large scale under present processes without these vast quantities of water. In the making of steel for instance, the industry is unable to secure equipment that will satisfactorily withstand the high temperatures which are required. It is therefore necessary to use water to cool bearings, to cool rolls and to cool furnace parts. Tremendous quantities of water are used in condensers at the plants where power is manufactured.

The steel industry recognizes as a problem its joint responsibility in stream pollution. In disposing of untreated wastes, both sanitary and industrial, the river is a convenience rather than a natural resource. We feel sure that no reputable industrial concern would demand for itself a special privilege of contaminating the river in any way to menace public health. The installation of dephenolizing plants and closing of abandoned mines bear witness to this fact. However, there have been many proposals made in various legislative bodies which to an industrial man seem radical. For example, there have been demands that the river be made free of acid. This would be a dangerous procedure unless provision is made for extensive treatment of sanitary wastes.

Acid and Sanitary Wastes Must Be Balanced

A paper entitled "Surveys for Stream Pollution Control"[1] by Harold W. Streeter, Senior Sanitary Engineer of the U. S. Public Health Service, Cincinnati, Ohio, contains the following statement: "The present benefit received from the presence of acid wastes in the upper river, although it appears to be confined largely to that section of the river and points immediately below it, is of such magnitude that the removal of these wastes, or their substantial reduction, doubtlessly will bring about a serious overburdening of

[1] Proc. A.S.C.E., **64**: 5 (1938).

purification plants both in this upper section and possibly at some points below Wheeling, unless provision is made for extensive treatment of sewage now discharged into the river, both directly and indirectly at points above Wheeling."

A paper entitled "Planning for Pollution Control at Pittsburgh" by D. E. Davis[2] contains the following statement: "It seems fair to conclude that if acid is materially reduced during low flood periods, nuisance conditions will unquestionably develop."

If the steel industry and the coal industry should be stampeded into neutralizing all acid wastes before provision is made for the proper treatment of sanitary wastes, cities along the river would be confronted with a very difficult problem of financing and constructing additional purification plants. The fact that a proper balance between sanitary and acid waste must be maintained in the upper river, especially during low water periods, and that the reduction of each must parallel the other is clearly indicated by most recent studies.

The question of financing and public economy must also be considered. It is our understanding that the U. S. Army Engineers, in their study of flood control projects, weigh the cost of any construction which would lessen the severity of floods against the reduction of loss occasioned by the floods. If the reduction of loss promised is not sufficient to justify the expense, the project is presumably not recommended. As a matter of public economy this seems like sound financing and good engineering, the principles of which might well be applied to pollution control.

We believe the problem of pollution control is a joint problem which can best be solved by confidence and cooperation between all concerned in its solution. To this end the American Iron and Steel Institute, through the Mellon Institute of Industrial Research has started an intensive study of problems relating to pollution of streams resulting from waste products of steel plant operation.

Fortunately the science of sanitary engineering and water purification, by correct design and skilled operation of water purifying systems, has been able to meet all requirements up to now. There is every reason to believe that future demands can be met through cooperative research and planned control.

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[2] Proc. A.S.C.E., **64**: 50 (1938).

Water Systems on the Ohio River

By Paul D. Simmons

A SURVEY of water systems on a portion of the Ohio River may be of value to the reader in attaining a general conception of the facilities and methods employed. With this general picture the reader will be able to judge what effect a change in the quality of the Ohio River may have on operation of existing water works. The survey here given begins with East Liverpool, Ohio, which is 43.5 miles by river below Pittsburgh, and ends with Moundsville, West Virginia, which is 58 miles by river below East Liverpool.

At East Liverpool, the water works is owned and operated by the city. The supply is taken directly from the Ohio River and is treated in the filtration plant by using alum, carbon and hydrated lime. After sedimentation the water is filtered through six filters, each of one-million-gallon capacity; then it is post-chlorinated. The daily consumption is 3 million gallons, about 15 per cent of which is used for industrial purposes. The city has 6,000 services, 2,800 of which are metered. A reserve supply of 8,700,000 gal. is maintained in three reservoirs and two standpipes.

The water works at Chester, W. Va., is owned and operated by the South Side Water Company. A crib system is used at the edge of the river, the crib being 80 by 16 ft., 6 ft. deep, and covered with 14 ft. of gravel and sand. The water flows by gravity through an 18-inch pipe, 180 ft. long, into a wet well. From this point the water is chlorinated at the rate of $6\frac{1}{2}$ lb. per 24 hr., and pumped into the distribution system. One thousand services use approximately 300,000 gal. of water daily, 30 per cent being used for industrial purposes. The pumps are located 3 feet above pool stage and protected against a 55-foot crest in the river. The uniformity of the

A paper presented at the Central States Section meeting at Wheeling, West Virginia, August 17, 1938, by Paul D. Simmons, Chemist, Weirton Improvement Co., Weirton, W. Va.

water is such that no trouble is ever encountered in the distribution system.

The water system at Newell, W. Va., is owned and operated by the North American Manufacturing Company. Newell has two sources of supply, one being a dug well 83 ft. deep and lined with a porous lining of 30 in. inside diameter. Each joint is 48 in. long and 5 in. thick. The other source of supply is a crib in the Ohio River. This system is pumped $3\frac{1}{2}$ hr. every Sunday to insure a satisfactory emergency supply of water. The porous well is pumped about $7\frac{1}{2}$ hr. daily, delivering to the distribution system approximately 675,000 gal. The reservoir has a capacity of 1,500,000 gal. The water is treated only with chlorine, carrying a residual of .15 parts per million. Newell has about 500 services.

The Wellsville, Ohio, water works is owned and operated by the city. Its supply comes from several springs and a small stream which feeds into a reservoir that has a capacity of 140 million gallons. The water is treated only with chlorine and at a rate of 6 lb. per million gallons. The average consumption is 1,500,000 gal. daily. Approximately 26 per cent of this water is used by industry. Wellsville has a population of 8,000 and 2,300 services. A new modern filtration plant is located at the reservoir. The city is being 100 per cent metered. The average hardness of the water is 2.6 grains per gallon. At times during seasonal rains, the water supply becomes muddy, and this is the major reason for the installation of the new filtration plant.

New Cumberland, W. Va., has two sources of supply, one being a well 1,200 feet deep and the other a group of 9 springs. The water flows from the springs into the well and is then pumped $4\frac{1}{2}$ miles to 4 tanks with a total capacity of 200,000 gal. A reserve supply of 3 million gallons is fed into a reservoir by springs, this supply being maintained for emergency use. The water is treated only with chlorine, a residual of 3 p.p.m. being maintained at the reservoir. Paul Cullins owns and operates the source of supply, furnishing water to the city whose daily consumption is about 40,000 gal. for 500 consumers.

Toronto, Ohio, owns and operates its water system, its source of supply being the Ohio River. The water is pumped into the plant and treated with alum and lime, the retention period in the coagulation basins being 8 hours. The water is filtered through 2 one-million-gallon filters, then chlorinated, retaining a residual of .15 p.p.m.

Approximately 400,000 gal. daily is pumped into the distribution system. The reservoir capacity is $3\frac{1}{2}$ million gallons, about 25 per cent of the water pumped to the city being used for industrial purposes. Toronto is metered 100 per cent with 1,650 services.

The Weirton Improvement Company at Weirton, W. Va., furnishes water for that city as well as Hollidays Cove and three subdivisions. The source of supply is the Ohio River. The water is treated in the coagulation basin with ammonia and chlorine (ratio 1 to 4), ferrous sulfate, lime and activated carbon. The finished water has a pH of 9.2. After sedimentation the water is filtered through four filters. After each filter washing, carbon is added to the filters at the rate of 6 lb. per million gallons of filter area. After filtration the water is pumped into the distribution system. The daily consumption for 1937 averaged 800,000 gallons (minimum—650,000 and maximum—1,200,000 gallons). Thirty-nine per cent of all water pumped to the city was used for industrial purposes. The total number of services is 3,116.

Steubenville, Ohio, owns and operates its water works, obtaining its water supply from the Ohio River. The river water is pumped into a preliminary settling basin of 6 million gallons capacity, then pumped into the filtration plant. Alum and lime are used for coagulation and post-chlorination for sterilization. With 8,200 services, the consumption is 3.5 million gallons daily, of which 16 per cent is used for industrial purposes. The total capacity of the distribution system is 10,500,000 gal.

Follansbee, W. Va., gets its water supply from an 18-inch drilled well, 85 ft. deep and 800 ft. from the river. The water is pumped into the distribution system and the excess from this pumping operation is directed into a 1,500,000-gallon open reservoir. Follansbee has 950 services using 1,200,000 gal. daily, with very little of this amount being used for industrial purposes. The temperature of the water coming from the well is 45°F. No treatment is employed in this system.

Mingo Junction, Ohio, secures its water supply from a cribbing system in the Ohio River. Water is chlorinated and pumped into the distribution system which has a reservoir capacity of 475,000 gal. Mingo has 1,575 services, 75 of which are not metered. The daily consumption varies from 300,000 to 400,000 gal. with only a small amount being used for industrial purposes.

Wellsburg, W. Va., depends on two wells for its water supply,

each 70 feet deep. This water is aërated to eliminate the manganese, then softened by the zeolite process and chlorinated. Wellsburg has 1,450 services with a daily consumption of 500,000 gal. Twenty per cent of this amount is used for commercial purposes. The capacity of the open reservoir in Wellsburg is 1,800,000 gal.

Tiltonsville, Ohio, has two deep wells from which it obtains its water supply. The water is chlorinated and pumped into a 200,000-gallon tank. Some 430 services use approximately 70,000 gal. daily, with 15 per cent of this amount being used for industrial purposes. The total daily capacity of the wells is 1,300,000 gall.

Yorkville, Ohio, gets its water supply from one well, from which water is pumped into the distribution system. A reservoir of 150,000 gal. capacity is included in this system. The only treatment is chlorination at the rate of 2 lb. per day. Four hundred services use approximately 125,000 gal. daily, with no industries drawing on the system.

Martins Ferry, Ohio, maintains a group of 7 wells from which it obtains its water supply. Each of these wells is 70 ft. deep. The only treatment is ammoniation and chlorination (1 to 4 ratio). Martins Ferry has 3,600 services, with a consumption of 3.5 million gallons each day. Approximately 50 per cent of this amount is used for industrial purposes.

The source of water supply for the Wheeling, W. Va., water works is the Ohio River. This plant furnishes water for Wheeling, Benwood and McMechen, W. Va. The water is treated with iron sulfate, lime, ammonia, pre-, intermediate-, and post-chlorination. The average dosage of iron sulfate is .05 grains and lime .8 grains. The final pH is 8.9. The entire distribution system has 16,800 services using approximately 9,300,000 gal. daily. The amount used by industries varies from 3 to 5 m.g.d.

Bellaire, Ohio, draws its water from the Ohio River. The water flows by gravity through a 36-inch strainer pipe into the plant, where it is treated with alum (0.57 grains), lime (1.5 grains) and post-chlorinated, carrying a residual of .15 p.p.m. The average amount of water used is approximately 3 m.g.d., part of which is used for industrial purposes. An open reservoir at this city has a capacity of 1,750,000 gal. (This plant was inundated during the St. Patrick's Day flood of 1936.)

Moundsville, W. Va., obtains its water supply from 11 wells, averaging 20 ft. in depth, cased with 12-inch casing and located on a

sand bar along the Ohio River. From 1.5 to 2 million gallons are pumped by steam each day from these wells. Moundsville has three other wells north of the city which furnish 1,250,000 gal. of water daily. The city water is treated with lime to obtain a pH of 7.2 and with chlorine for sterilization. Approximately 50 per cent of the water treated is used by industries. The distribution system has 3,200 services and a reservoir of 2-million-gallon capacity.

During the past year the Ohio River has had less acid than in previous years, due, probably, to neutralization of coal mine drainage and to less industrial waste. The increase of alkalinity in the river evidently has promoted the growth of algae and micro-organisms, since the filtration plants using river water have reported trouble with the organisms in plant operations this season. It will be noted that the filtration plants that obtain their water supply directly from the Ohio river all use preventative measures to control taste and odor.

National Water Policy

Committee Report

To the Board of Directors,
American Water Works Association

THE Committee on National Water Policy recommends that the Board of Directors of the American Water Works Association affirm the following general principles as a guide to the Committee on National Water Policy for participation in current hearings on legislative issues dealing with water resources.

(a) No further extension of basic federal control over streams is desirable at this time.

(b) The federal government should restrict its activities in fields such as pollution abatement, to fact finding on, co-ordination and stimulation of, and financial assistance to state and interstate programs, so as to promote the solution of such problems consistent with other important national requirements.

(c) The initiation, administration and financing of projects largely of non-federal character should be reserved for state and interstate action.

The Committee further proposes for adoption the general principles and definitions regarding a national water policy set forth below:

1. A unified plan of water control and development calls for an

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A report submitted by the Committee on National Water Policy. Members of the Committee are: Louis R. Howson, Consulting Engineer, Hinsdale, Ill.; Theodore A. Leisen, General Manager, Metropolitan Utilities Dist., Omaha, Neb.; Samuel B. Morris, Dept. Civil Eng., Stanford University, Calif.; Howard S. Morse, General Manager, Indianapolis Water Co., Indianapolis, Ind.; and Abel Wolman, Professor San. Eng., Johns Hopkins University, Baltimore, Md. This report was approved by the Board of Directors of the A. W. W. A. at its annual meeting in New York on January 18, 1939.

integrated national policy with respect to the various types of water problems in their interlocking relationships, in contrast to a collection of more or less unrelated policies on water supply, water pollution, flood control, irrigation, water power and navigation.

2. A sound national water policy must have the following characteristics:

(a) It will seek through integrated control of the uses of water to promote public health, safety and welfare.

(b) It will hold facts to be indispensable prerequisites to action, which in turn shall rest upon economic soundness.

(c) It normally will treat drainage areas as units.

(d) It will observe the rights of states both in interstate and intrastate streams.

(e) It will assign the cost of constructing and operating projects to the functions and among the agencies and the levels of government concerned in general accordance with the distribution of benefits.

3. Such national water policy should promote co-operation between and with the several states, not only on the management of interstate streams but also in the intrastate streams. Such co-operation should be a two-way proposition with reciprocal responsibility between the states and the federal government. Every state has responsibilities, no less than rights. These responsibilities cannot and should not be shifted to the federal government.

4. The concept of the unified control and the development of river systems for all useful purposes is relatively new and naturally has not yet been reflected either in local or national policy. The transition from a group of separate policies dealing with particular problems of water use to an integrated national policy that will establish broad principles of action should be gradual and consummated over a period of years.

5. To move toward these objectives the following principles and programs should be developed:

(a) A National Resources Committee should be permanently established to integrate the operations of the Nation in the fields of land, water and mineral resources.

(b) A primary unit in the National Resources Committee organization should be one devoted to undertaking a similar task of integration and stimulation in the field of water resources use and development.

(c) Such a water resources unit should be sufficiently large to include representatives from federal agencies primarily concerned with problems of water, balanced by representatives from the states and other levels of government and from other interested groups in the water field.

(d) This water resources unit should have as its primary functions the development of a national water policy, the integration of operations on the federal level and the stimulation of co-operation with state and other levels of government.

(e) In general, the operations of the water resources unit should be through drainage basin committees composed of representatives of all interested governmental and private agencies within such drainage basins. Such drainage basin committees should be primarily advisory, co-ordinating and integrating agencies working under the direction of the water resources unit of a National Resources Committee. Activities in the field of detailed investigation, planning and construction of projects and their detailed design should be reserved to appropriate existing bureaus of the federal, state and local subdivisions of the government. For the most part much of the activity of a water resources unit should depend upon the co-operation and performance of state, local and regional group representatives composing the several drainage basin committees.

(f) This water resources unit should have the further functions of establishing priorities for project selection and of determination of allocations of funds for water resources works, paralleling and supplementing similar activities of the National Resources Committee in the general public works and other fields.

Personnel of the National Water Policy Committee

Louis R. Howson
Theodore A. Leisen
Samuel B. Morris
Howard S. Morse
Abel Wolman

Submitted by Abel Wolman, *Chairman*

Organization of Water Resources Planning

By Harlan H. Barrows

WATER planning calls for collective action and therefore for organization. Planning and organization for that purpose coalesce in practice, and certain propositions with respect to planning may well be recalled and reaffirmed at the outset of even a brief discussion of organization.

Water planning is essential to public welfare. This statement is by no means axiomatic in the opinion of all people. The report of the Committee on Flood Control of the House of Representatives on the flood control bill of 1938 (Report No. 2353 on H. R. 10618) states that "The committee believes that the Congress and the country have had enough of theoretical planning. It is time for action." Theoretical water planning, in the sense of planning wholly dependent on, or confined to, theory or conjecture, is reprehensible, but practical planning, based on adequate investigation and reliable data, is indispensable to social progress. Unplanned action with respect to water problems of magnitude is foolhardy; inadequately planned action is rash.

Much fancy and too little fact underlie many existing water plans, the fulfillment of which would cost vast sums. The so-called Markham plan of April, 1937, for the control of floods on the Ohio and Lower Mississippi Rivers, sponsored by the House Committee on Flood Control and adopted by the Congress in the Flood Control Act of 1938, is a striking example of such plans. The Subcommittee of the Water Resources Committee on the Ohio-Lower Mississippi River Regulation Program, of which General Schley, the present chief

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A paper presented to the Association of Western State Engineers at Phoenix, Arizona, December 9, 1938, by Harlan H. Barrows, Chairman, Dept. of Geography, University of Chicago; Member, Water Resources Committee of the National Resources Committee.

of Army Engineers, is a member, began its first progress report, dated October, 1937, with these arresting statements: "The public seeks effective protection in the near future against floods of maximum height along the Ohio and Mississippi Rivers. It assumes that a suitable plan exists for such protection. Unfortunately, this is not the case. Even the knowledge on which a comprehensive plan must be based is lacking. . . . Large expenditures should now be made only for those projects which are found to be meritorious in the light of adequate and reliable data, and which later would fit into a truly integrated water and land plan. The interlocking problems of these mighty rivers cannot be solved by measures conceived in haste and carried out in unrelated fashion. The public welfare demands recognition of these patent facts."

Small wonder, for these and other reasons, that the President approved the Flood Control Act of 1938 with avowed reluctance. Small wonder, perhaps, that the general public supported the measure. It was clamorous for flood protection, accepted with credulity the proposals for protection, and rejoiced over the prospect of shifting to the nation at large much of the cost of protection which had rested earlier with local beneficiaries. The bright hope of gain through large federal aid under the policy adopted in the Flood Control Act of 1938 already is dimmed in many communities by the dark fear of loss through wide extension, under that policy, of federal authority over streams.

More Sound Water Planning Needed

A "pork barrel" unprecedented in size has been constructed, state authority over non-navigable streams has been threatened anew, and the integrated regulation and optimum use of many rivers have been jeopardized. These untoward denouements, like many others in the field of water resources that might be cited, illustrate the fact that the Congress and the country have not had nearly enough *sound* water planning. Water planning, I repeat, is essential to public welfare.

Water planning will be needed indefinitely. The future water requirements of most areas can be estimated only approximately and for comparatively short periods. They will be affected by changes in population density, in land use, in business and industry, and in social conditions. These changes will be affected in turn by the supply of water. The supply now available may be insufficient even for

present needs. The extent to which it can be increased may be unknown. The total supply, available and potential, may change because of natural processes or human action. For these reasons, dynamic plans, not static plans, will be needed. For these reasons, planning without end will be needed.

To the greatest degree practicable, water planning should relate to the associated problems of unit areas, not to particular problems in isolation. Experience is demonstrating, ever more clearly, that the water problems of any area are likely to be so closely interconnected that they cannot well be separated. If an attempt be made to deal with each type of problem by and for itself, for example with irrigation, or flood control, or power development, or navigation, then overlap of effort, waste of funds, and partial accomplishment inevitably result. There is probably not a single undeveloped storage project of significant size in all the West that does not have multiple potentialities, and yet many such projects have been appraised recently from particular and restricted points of view by different federal agencies between which there was no coöperation. The desirability, in such instances, of complementary and coördinated investigations leading to integrated plans is obvious. Lip service to the principle of coöperation avails little. Bureaucratic competition for opportunity and power looms large.

Planning Demands Wide Cooperation

It is probably true that no two drainage areas, even if contiguous, present identical associations of water problems. They may present the same types of problems, but almost certainly they will be found to differ in the relative significance of some of the types. Moreover, the water problems of each drainage area, large or small, are distinctively interrelated not only among themselves but also with problems of land occupation and use, of business and industry, and of social life. Water problems project themselves into every phase of earth economy. Effective physical planning, whether it pivot on water resources, land resources, or mineral resources, requires recognition of all significant interrelationships among the natural and cultural factors involved. An integrated regional approach to a complex of interlocking problems is likely to prove far more fruitful than a series of unintegrated functional approaches. The specialized functional approach usually has been followed. Only in recent years has emphasis shifted somewhat, even among planners and engineers,

to the coördinated control and development, for all useful purposes, of the water resources of unit areas. The old approach lacked perspective. It tended to obscure a unified view of the sum total of problems and potentialities in different regions. The new approach facilitates the attainment of maximum total benefits at minimum total costs. It calls, not for the elimination of specialized investigations, but for their reconciliation one with another and their coördination into a comprehensive and unified program. It calls for close coöperative efforts by agencies that heretofore have worked together but little.

Logic and experience indicate that river basins are normally the best units for integrated water planning. This results from the mobility of water and the hydrologic unity of river basins. In most instances, they cannot be divided satisfactorily for major planning purposes. Large-scale measures for the control and use of water in different parts of a basin must be harmonized if maximum benefits are to be achieved. The upstream and downstream segments of most basins cannot well be treated separately. Plans and programs for interstate rivers cannot stop at state lines. Every benefit that may be derived from the mutual adjustment and integration of related purposes throughout each basin should be recognized and promoted.

Planning Extends Beyond the Drainage Basin

Full recognition of the unity of river basins in over-all water planning should not result, of course, in disregard of the fact that many problems transcend the boundaries of basins or the fact that within basins of large size there are many problems having only local significance.

Although the Tennessee Basin is a well-defined unit, the first sale of power by the Tennessee Valley Authority was to consumers outside the basin. The limits of the basin did not delimit even the earlier plans and activities of the Authority. In the Colorado Basin, a question of outstanding importance involves the extent to which water itself can be exported from the basin with equity and advantage. In the Pacific Northwest, reclamation is pushed to help relieve distress caused in part by droughts in the Northern Great Plains. If the more pervasive problems of water are to be solved satisfactorily, basin planning must be tied firmly into regional and national planning.

Along the tributaries of any large river there are problems that can be solved without significant effect upon the river system of which the tributaries are members. The problems in question are those that do not materially affect problems of wider scope and are themselves not materially affected by the latter. They comprise the distinctive field of local planning. Except for them, local planning must be tied closely into basin planning if water is to render full service.

I have asserted, categorically or in substance, that water planning is indispensable to public welfare; that unplanned action or inadequately planned action with respect to large water problems is deplorable; that ill-advised action in the past jeopardizes the future; that the need for scientific water planning will never end; that effective planning presupposes adequate and reliable data; that uncoördinated planning in particular regions by individual agencies for single purposes should give way to joint planning by all the agencies for all the useful purposes which are attainable and feasible; that drainage areas should normally be treated as units with respect to their larger water problems; that some basin problems merge into regional and national problems; and that some water problems have only local importance.

These assertions, if valid, indicate needs in water resources planning that call insistently for long-time, coördinated effort by federal, regional, state, and local agencies. Such effort in turn necessitates effective organization at all these levels.

Proposed Permanent Federal Agency Described

A permanent statutory Federal Agency is needed to insure coöperation between federal departments and bureaus in the investigation of water problems and the formulation of over-all water plans; to review, in an advisory capacity, the water plans of different federal agencies or coöperating groups of agencies; to provide counsel and advice to state and local water planning agencies; to organize and guide joint investigations of interstate water problems as a basis for compact negotiations, if desired; to help coördinate interstate, state, and local water planning activities, on the one hand, with federal activities, on the other; to check proposals for federal expenditures in the field of water resources in the light of national policies and of interregional relationships, and to advise the Bureau of the Budget with respect to them; to carry on investigations needed to supplement or integrate

the investigations of other agencies concerning water resources; to submit annually to the President and through him to the Congress integrated programs of related federal activities with respect to water, for executive and legislative consideration; and to perform other comparable and appropriate duties designed to promote the integrated regulation and development of the nation's water resources for all useful purposes in good proportion. Such a federal agency, charged with suitable duties relating not only to water but also to other resources, perhaps under the title of the National Resources Board, should have no executive authority. Projects authorized and financed by the Congress should be designed, constructed (or otherwise carried out), and managed by the appropriate departments of the government.

No adequate federal agency now exists for the purposes indicated. The National Resources Committee has done much good work, I think, but it leads a precarious existence under Executive Order, without statutory recognition and without either the authority or the funds to deal adequately with the situation. No department or bureau could exercise the functions that have been indicated. No interdepartmental committee would be adequate.

Board to Have Nine Members

The new statutory board that is needed might well consist of the Secretaries of the Treasury, War, Interior, Agriculture, Commerce, and Labor, and three persons to be appointed by the President by and with the advice and consent of the Senate. The members last mentioned should be chosen, one from the East, one from the Interior, and one from the West, to the end that the interests of the entire country may be represented. The chairman of the board should be designated by the President. I think that no advisory committee to the board, corresponding to the Advisory Committee of the existing National Resources Committee, should be established by statute, but the board should be empowered to create and maintain, so long as needed, *any* committees that may be required to carry out its designated functions.

The board should also be empowered, of course, to appoint an Executive Secretary, to define his duties, and through him to set up a competent staff of requisite size, for the prosecution of its work in Washington and elsewhere, consisting in part of per annum employees and in part of per diem consultants, subject to call as needed. Through

the activities of such a board and staff the theory and technique of coördinated over-all planning, both of which are still in a rudimentary state, would be perfected in time, and water planning would be lifted to a new level of accomplishment.

Such a board and its staff would not duplicate activities now performed by other agencies, but would help to bring those activities into focus and perspective, to fill gaps and eliminate overlaps, to promote collaboration, to protect essential public interests in water, to foster economy, to insure wise expenditures for the control and development of water resources, and to secure maximum benefits from such expenditures.

The view that national planning should be organized on a regional basis has gained momentum in recent years and has led to a variety of proposals for the creation by Congress of regional planning bodies. I do not believe that an integrated approach to the associated problems of unit areas, in other words a *regional* approach, requires the establishment by statute of new regional agencies. I believe that the advantages of a regional approach to the requirements of a moving national water plan can be gained without such agencies. To grant them executive authority, *if* established, would be unwise. If that were done, there would be grave danger of encroachment upon the rights of the several states and of unwarranted assumption of some of their responsibilities. There would be grave danger, too, that various activities of existing federal agencies would be wastefully duplicated or needlessly superseded. To say the least, the early esestablishment, throughout the country, of authorities of the Tennessee Valley Authority type would be premature. Not for years can the advantages and disadvantages of that experiment be clearly appraised and balanced. We proposed to learn lessons from it. We need time to do so. And time, it may be added in the words of an old French proverb, "pays little respect to that which is done without it."

Cooperation Among States Will Obviate Federal Control

In general, the more troublesome regional problems of water relate to interstate rivers, many of which present issues that lie between the realm of established state authority and that of established federal authority. The best way to deal with these problems is through coöperative investigations and neighborly negotiations, participated in by appropriate agencies representing the interested states and the

federal government, with a view to equitable compromise and adjustment of conflicting interests and claims. This is in accordance with a fundamental principle of democracy—the principle of compromise. The alternatives to this procedure should be shunned. The alternative of litigation is slow and costly, and the results are likely to be inconclusive and unsatisfactory. The alternative of further extension of federal authority over the water bodies of the country is a potential threat to the maintenance of our democratic system. There is no need for either alternative. Earnest coöperation in a spirit of equity is the only indispensable prerequisite to satisfactory agreements on the allocation of the waters of interstate streams or on plans for their regulation and development.

The National Resources Committee has assiduously promoted joint factual investigations of critical interstate problems, believing that controversies yield to facts and that negotiations based on established facts are likely to produce results acceptable and fair to all concerned. Such investigations may necessitate special organizations adapted to particular circumstances. Examples are afforded by the investigations on the Red River of the North and the Upper Rio Grande.

Three States Cooperate on the Red River

In July, 1935, the Governors of Minnesota, North Dakota, and South Dakota called an interstate conference to consider the critical water problems of the basin of the Red River. The conference decided that an integrated water plan for the entire basin should be formulated as a prerequisite to effective action. At a second conference, in November, 1935, an interstate committee was set up to undertake the investigations essential to the proposed plan. Two representatives of the National Resources Committee were elected members of the committee by the conference, and one of them, W. W. Horner, served as its chairman. The work of the committee was carried on largely through the state planning boards. Specific studies were undertaken by the water engineers and sanitary engineers of the states. Assistance was rendered by the Corps of Engineers, the Geological Survey, and other federal agencies. Committee meetings were attended by interested state and local officials. Field meetings were held, at which local problems were presented by local men and the work of the committee was discussed. A report of the investigation was completed in December, 1936.

In addition to presenting a coördinated water plan, the interstate committee recommended an interstate organization with power to control the water resources of the basin within the United States and to levy limited assessments on the beneficiaries. This organization, under the title of the Tri-State Waters Commission, is now functioning under an agreement drawn jointly by the attorneys general of the three states and acted upon by the legislatures in 1937. From first to last, the investigation, the development of the plan, and the formulation of a program of action under the plan, were primarily interstate enterprises, most of the work being accomplished through the joint efforts of state and local officials.

The Rio Grande Joint Investigation grew out of a conference at Santa Fe in December, 1935, between representatives of the National Resources Committee and the Rio Grande Compact Commissioners and their advisers. The object of the conference was to determine whether or not the National Resources Committee and the states could coöperate in gathering facts that might be helpful to the Commissioners in making an equitable division of the waters of the Rio Grande above Ft. Quitman, Texas, among the states of Colorado, New Mexico, and Texas. At the conclusion of the conference, the Compact Commissioners adopted a resolution which reads in part as follows:

> Now therefore, be it resolved, That the National Resources Committee, through its Water Resources Committee, be requested, in consultation with the members of the Rio Grande Compact Commission, to arrange immediately for such investigation (1) of the water resources of the Rio Grande Basin above Fort Quitman, (2) of the past, present and prospective uses and consumption of water in such Basin in the United States and (3) of opportunities for conserving and augmenting such water resources by all feasible means, as will assist the Rio Grande Compact Commission in reaching a satisfactory basis for the equitable apportionment of the waters of the Rio Grande Basin in the United States above Fort Quitman. . . .

The cordial willingness with which the Compact Commissioners entered into the undertaking and supported it throughout exemplified constructive statesmanship. A consulting board was responsible to the Water Resources Committee for the organization and conduct of the investigation. The board took no action of importance with respect to the personnel of its field force charged with immediate

administration and coördination of the work, the allocation of funds, or the assignment of major units of work without the advice and approval of the Compact Commissioners. The investigation was carried out in coöperation with the United States Geological Survey, the Bureau of Reclamation, the Bureau of Agricultural Engineering, and the Bureau of Plant Industry, with material assistance from the Bureau of Indian Affairs, the Resettlement Administration, and Soil Conservation Service. Various other organizations, federal, state, and local, provided services, materials, records, office or laboratory space, and the like. The requisite funds, approximating $394,000, were provided by the three states and several federal agencies. Following the completion of the investigation, in the summer of 1937, negotiations were undertaken by the Compact Commissioners that resulted in a compact signed on March 18, 1938. Undoubtedly the compact will be ratified by the state legislatures and approved by the Congress this winter. Thus a great region, released from bondage, will be free to develop all the potentialities of its life-giving waters.

The Red River and Rio Grande investigations, very different one from the other, alike demonstrate the practicability of a coöperative attack upon the basic problems of an interstate river by existing federal, state, and local agencies, aided, when desirable, by a special coördinating unit set up only for the duration of the enterprise. There is wide range for experimentation in the detailed organization of such undertakings. Their adaptability is one of their more commendable features. They probably will not be novel a few years hence.

Vigorous and sustained action by the states and minor civil divisions, no less than by the federal government, is required to bring about the most beneficial use of the country's limited water resources. It is a matter not only of equity but also of necessity that they participate fully in developing and carrying out harmonious plans, a matter of necessity because the federal government is powerless to act along various essential lines. National planning and state planning are complementary necessities.

Many states have venerable departments, bureaus, boards, or other agencies, that deal with special aspects of water planning. A quarter of a century ago most of them had Conservation Commissions that made investigations and proposed measures for the conservation of all natural resources. Some of these commissions accomplished much of value. Many did little of significance. Most of them long

since ceased to function. Five years ago the state planning movement was revived, partly, no doubt, as a means of securing the largest tangible returns from federal expenditures for public works and work relief. Early this year 45 states had planning boards. A few also have boards or commissions that deal exclusively with water problems. The planning boards apparently differ much from state to state in their organization and in their place in the complex of official agencies.

Most of the boards necessarily have devoted much energy thus far to defining objectives, to setting up procedures, to collecting basic data, to establishing working relations with other governmental agencies, and to preparing preliminary reports in response to current demand. More and more, doubtless, they will devote themselves to the formulation of mature, comprehensive state plans, effectively related to local and federal plans.

From some angles, the future of state planning is obscure. It has not yet "found itself." The need for it is not sufficiently appreciated in some states and it is inadequately financed in most states. If the financial support of the National Resources Committee were withdrawn, many state planning boards probably would cease forthwith to function. Since coördinated state planning is a social necessity, however, any lapse, whatever the cause, would be impermanent.

The National Resources Committee has stimulated and supported state and local planning in every way within its power. It maintains field offices at appropriate centers, and with the aid of a corps of regional chairmen and regional counselors provides close-range counseling and consulting services. Through its Water Resources Committee it has organized forty-five drainage basin committees throughout the country, on which there is large state and local representation. Any permanent national planning agency should continue this policy of helping states and communities to solve their own problems, to plan the use of their own resources, to shape their own destinies. This is the proven way of democracy.

The organization of water resources planning should remain flexible. The mechanisms through which the federal government and the states can best exercise their water planning functions may vary in detail from time to time with changing conditions. All the major questions of policies, plans, organizations, and procedures now confronting the public with respect to water resources should be given an adequate forum. The decisions to be reached are of great significance to the future of the nation.

Discussion by *L. Ward Bannister*.* Dr. Barrows, to my knowledge has done some very valuable work for the benefit of the states in this part of the country. His address shows wide knowledge of the water problems both of the East and of the West.

I find from it what he has manifested on other occasions—a recognition of the principle that the general control of the streams of the country is in the states rather than in the federal government and that the water problems of the country should be worked out by the federal government and the states on a basis of coöperative consultation and action. He would develop the use of the country's waters largely according to drainage areas, although recognizing the fact that occasionally the direct benefits of such development would be carried over into a basin not the one of water origin.

In the case of interstate stream problems, he recognises the principle that each state has a right to a fair amount of the waters of the common stream and that the principle of interstate compact consented to by the federal government as required in the Constitution, is to be employed. Dr. Barrows himself has lent substantial aid to bring about complete negotiations for interstate compacts now pending in some of the legislatures of the western states.

At the suggestion of the Editor of this Journal, I am appending herewith excerpts from an address entitled "National and Regional Planning for the Use of Our Country's Waters" which was delivered by me at the National Reclamation Association at Reno, Nevada, October 13, 1938. These excerpts, which follow, appertain closely to the subject matter developed by Prof. Barrows.

That national planning in the sense of planning by the Nation and on a scale that includes within its field more than a single state, is necessary to the conservation of our waters, soil, forests and minerals, is clear. There are monster rivers to be held in leash, especially in the eastern half of the continent; lands to be reclaimed by irrigation in the West; areas to be reforested both East and West, forests to be protected and soil erosion to be checked. These things we undertake partly for ourselves, but more that we may transmit to coming generations an inheritance that will make their lives endurable and keep America great.

The task in its entirety is too great for the individual or the cor-

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poration, and in view of, indeed regardless of, interstate problems, is often too great even for a state. Necessity, therefore, imposes much of the duty upon the government. For its discharge there must be planning participated in by the government, not only in fields comprising single states, but in those of many states.

Government or national planning we have already—national planning by the Bureau of Reclamation to reclaim lands through the application of water rather than to allow it to run at will in waste to the sea; by the Army Engineers to protect farms and cities from the floods; by the Forest Service to protect existing forests and create others; by the Soil Conservation Service to encourage fertilization and to protect from erosion that top layer of vegetable decay or humus to create a single inch of which requires a century. These various agencies not only plan, but, when authorized so to do by the Congress, execute these plans by constructing the projects or carrying on the planned activities. Some of the bills to which reference has been made confer upon the proposed Federal Corporate Agencies authority not only to plan but to operate and control projects and activities.

Legal Aspect Sometimes Ignored

The National Resources Committee functioning under a temporary 1935 Executive Order, and availing itself in part of the data of other departments, but also adding the results of its own researches, is doing a notable piece of work in the field of water uses. The work has been marred somewhat by the failure to recognize states as states, sufficiently, in the planned distribution of water-uses from streams that are interstate in character, and to exact interstate compacts in order to protect one state against the other, thus ignoring the legal factor, as distinguished from the engineering, in water problems. I have often thought and when no engineers have been present, have ventured to suggest: that a water engineer and a water lawyer are alike in one respect, namely, each is only half a man, but that they differ in that while the water lawyer knows this, the water engineer apparently does not.

With national planning already in existence by various agencies of the government—competent at that—what more is needed? The answer is a permanent coördinating statutory agency. Call it a National Resources Board if you will, the primary function of which would be: not to construct and operate projects authorized by the

Congress, but rather to investigate and consider the plans of the other federal agencies now acting more or less independently, and of states and municipalities; to coördinate these plans and present to the Congress and the President those of the plans favored by the Board, subject to the approval of the federal agencies regularly charged with the planning in the particular field concerned.

In any organized scheme of national planning we cannot put soil, water, minerals and forests in air tight compartments. Complete conservation of one of these resources involves and affects the others. Indeed, even as to water alone there may be single or multiple uses such as irrigation, flood control and power, all of which must be considered in determining the location and character of structures. Not only is all this true physically but financially as well. It may be a bit old fashioned to suggest that there is any ceiling on national expenditure short of Orion and the Pleiades. Yet a limit does exist, and must be kept in mind, along with the needs of the different areas of our country, in determining the relative importance and the order of conservation plans to be put forward to the Congress and the President.

Board Members to Come from Entire Country

Such a Board should consist partly of representatives of the Departments of War, Interior and Agriculture, under one or the other of which most of the planning agencies referred to are now functioning, but more largely of members chosen from the various areas, to the end that the interests of the entire country may be reflected in the investigations of the Board and the plans that it would submit to the Congress and the President. These members should be appointed by the President and confirmed by the Senate.

This proposal of a federal coördinating agency is a simple one. It avoids duplicating the investigations of other existing agencies; it provides expert opinion upon the relative value of different plans scrutinized in the process of coördination; it recognizes financial limitations and the interests of the country as a whole, and plans the activities accordingly. It sets up no regions with regional agencies or satrapies to lord it over the states. It gets along with existing federal agencies but coördinates their plans, presents the best of them to the Congress and the President, and leaves to the Congress the question of adoption and appropriation. Care should be taken that the coördinating agency does not go beyond planning for the

development of natural resources. It should not be permitted to go afield and plan for a general "planned economy" either of socialism, fascism, or nazism.

Before judging the method, we must consider some preliminaries. Of the four resources—forests, minerals, soil and waters—the first two, namely, forests and minerals, are geographically fixed. The same thing is true of the soil, except for the part of it that thumbs a ride on wind or stream. The fourth, water, is an element that, because of its migratory habit, raises questions of interstate character.

In the eastern half of the continent these questions are principally of dams and levees for flood control; the acquisition of rights-of-way for these devices; the division of costs as between the federal government and the states and as between the states themselves; the ownership and operation of the dams and power plants, whether by the federal government, or the state, or private enterprise; and the extent to which settlement of these questions may be had by interstate compact. There are also in the East the questions of diverting water from one watershed into another, as, for instance, in the controversy between Connecticut and Massachusetts from the headwaters of the Connecticut River into the area surrounding the city of Boston; and in the controversy between New Jersey and New York over the diversion of waters from the drainage basin of the Delaware into that of the Hudson.

Scarcity Is Basis of Western Problems

In the western half of the United States water is scarce. The interstate questions are principally, how to conserve and develop this resource in such wise by location and size of project as to make a fair distribution of water-uses as between the states, and also the extent to which interstate compacts, under the leadership of the government, may be used in the accomplishment of this aim. Here, too, as in the East there are also interstate questions arising through the transfer of water from one drainage basin to another, and involving more than a single state.

In this country two systems of water law prevail—the riparian and the appropriation. Roughly speaking, the former in the states east of the Missouri and the latter west. The fundamental principle of the riparian system is that each land ownership contiguous to the stream has a legal right to a reasonable use of the waters of a stream, subject to a like right on the part of other contiguous land owner-

ships. All ownerships are entitled to at least some water. The fundamental principle of the appropriation system, on the other hand, is that the use of water is not limited to land ownerships contiguous to the stream and that water users or appropriators, as they are called, are entitled to water only in the order of their priority in point of time. Under this principle there is often little or no water for the latest appropriators. That, however, cannot be helped. The water is scarce; there is no other principle that is so workable.

Federal Financial Aid is a Key Factor

Now it is evident that where water uses are desired in the East or West for industrial, municipal, recreational or irrigation purposes, federal financial aid to a project in one state may well prove a detriment to another state on the same stream. The other states, therefore, should keep a watchful eye. The detriment might lie in the inability of the other state to obtain financial aid for a project of its own until the federal government shall have gotten back its investment in the first state. This would be true in the East or West. Or the detriment might lie in the possibility that the priority principle might be applied as between states, instead of merely as among appropriators within the same state. In that event the state receiving the project through federal financial aid would acquire a water priority against the state not receiving it.

The conclusion is that in the development of water uses on interstate streams, whether in the East or in the West, more attention should be paid, than the government is bestowing now, toward securing a fair distribution of water uses to each state upon the same stream. Wherever the federal government is applied to for funds, there the government, through the control of the purse, has the opportunity to exact interstate compacts by suggesting what would be a fair division of water and then compelling its acceptance by otherwise denying financial aid to the state seeking the project, while at the same time threatening the objecting state with a grant of the financial aid desired regardless, should the latter not enter into the suggested compact. Under such a course the applicant state could not obtain the money without entering into the compact, and the protesting state would run the risk of adverse water priorities if the project were constructed without a protecting compact. The federal government should seek a fair division of water between

states, but should not permit states to block development by refusals to enter into compacts.

Why can not the present National Resources Committee, existing by executive order, be converted into such a statutory agency? There should be no regional Authorities or Conservation Planning Agencies whatsoever. Members of the proposed statutory agency or Board should be made up partly of representatives of the Departments of War, Interior and Agriculture, but more largely from the various parts of the country, and appointed by the President and confirmed by the Senate. There would be provisions in any such bill looking toward a fair share of interstate water to each state. There would be no assertion of that hated doctrine of ownership or general control of the waters of the states, since general ownership or control is in the states and not in the federal government. There would be such provisions in the bill declaring the supremacy of the laws of the states as are now to be found in the Hayden and the later Mansfield Bills.

Legislation Asserts State Ownership of Water

That the federal government rather than the states owns or controls the waters of the states is one of the express assertions upon which some legislation is predicated. The same assertion as to unappropriated waters in the West is being made at the present moment by the Department of Justice in behalf of the United States as an intervenor in the suit of Nebraska vs. Wyoming and Colorado pending in the Supreme Court and involving the waters of the North Platte. This assertion is made both as to streams that are navigable and those that are not. If we of the West concede the assumption of these bills and concede this contention of the Department of Justice, we surrender to the federal government the control and direction of the future water development of the states and open the way for Regional Authorities.

Why is the doctrine of federal ownership or control of state waters so hated? The states of the East do not tolerate it nor will the states of the West, although both regions recognize the very proper and necessary authority of the federal government under the commerce clause of the Constitution to promote navigation. For the opposition of the West there are reasons peculiar to it. They lie in the origin and history of the appropriation system and in its inherent

necessity for state administrative officials to grant permits and to distribute the waters among the millions of water users.

While the eastern states imported their riparian system of water law from France as the result of the studies, decisions and writings of Storey and Kent, the appropriation or priority system of our West was invented by the people of the West. It originated with the miners of California—those men of the red bandana and the gold-pan. The late Justice Field of the United States Supreme Court helped to develop that law when, in California and as a judge of a miners' court, he administered justice from behind a dry-goods box and when later he went upon the federal bench.

Priority System Recognized by Seventeen States

The late Moses Hallet, in the Colorado 60's, was demoted by his placer mining partners from placer miner to cook and then demoted again, as his partners saw it, to a judge of the miners' court because as a miner he was a poor man at the sluice box and as a cook he let the biscuits burn, all on account of his love for an old law book called "Blackstone's Commentaries." Later, and as Territorial and Federal Judge, Hallet, too, like Field, put his hand to the development of the same system of water law. That system has spread from California until it is now recognized by seventeen states of the West, by Acts of Congress and by judicial decisions of the Supreme Court. Seven of those seventeen states recognize riparian law in no particular whatsoever, the other ten recognize it to a small extent, but are trying to escape from it as rapidly as they know how. The federal government never had any property rights to water in the seven states, except when it was an ordinary appropriator, and such as it ever had in any of the other ten, or in any of the seventeen, it disposed of under the Acts of Congress of 1866 and 1877. If by chance the federal government makes an appropriation of water in one of these seventeen states, which of course it is free to do, it acquires an appropriation water right, but the right thus acquired is no different from that acquired by any private person and, therefore, is subject to the laws of the state in which it is situated.

Let us insist that the Congress itself perform and not delegate the legislative function of authorizing and allocating funds for water projects. The battle against Regional Authorities does not involve an attack upon government projects whether on the Columbia or

the Colorado or the far away Connecticut. It is an attack against new agencies to come between the Congress with its existing agencies on the one hand and the states on the other. We send senators and representatives to the Congress. They are of age and supposedly qualified. The Congress should retain, and not delegate, especially as to interstate streams, the determination of what water projects shall be constructed and where and also what funds should be allocated. It is only in the Congress that the affected states have a chance to be heard before committees and with their senators and congressmen as their helpers and protectors. Concrete instances could be cited, I could cite them, where the failure of the Congress itself to exercise this power has wrought injury to specific states. Let us remember that ballots alone do not constitute representative democracy. There must be in addition an active participation by the legislative representatives thus elected in the framing of the laws and of the policies under which our people are to live. This alone is real Representative Democracy—this alone the democracy that will long endure.

Committee on Water Works Practice

To the Board of Directors, American Water Works Association:

There is reported herewith the status of water works practice sub-committee activities as of January 18, 1939.

1. *Chemical Hazards in Water Works Plants.* A report on sulfur dioxide and caustic soda was presented to the Water Works Practice Committee during the New Orleans convention and has been approved. This report does not involve specifications or standards. It is a record of the chemical and physical characteristics of the materials under consideration and outlines certain recommended practices for the avoidance of accidents and the care of persons injured in the use of the chemicals. (The Board approved the report and ordered it printed in the Journal. See page 489.)

2. *Electrolysis and Electrical Interference.* The members of this sub-committee are also the representatives of the Association on the American Research Committee on Grounding set up under A. S. A procedure. C. F. Meyerherm is A. W. W. A. representative on the article 250 or Grounding Sub-committee of the N. F. P. A. Electrical Committee and on the A. S. A. Committee C1, sub-committee on Grounding. A statement from the Grounding Research Committee appeared in the November, 1938 issue of the Journal. (A conference of A. W. W. A. and N. E. W. W. A. representatives with certain members of your board was held on January 17.)

A memorandum was sent to all A. W. W. A. members on January 31, as follows:

"You are advised that while the practice of grounding electric service lines on domestic water service pipe is in effect in many cities, the water department does not place the connections, derives no benefit from them, may be damaged by them, and tolerates them only because of their reputed importance in providing electric service. While the water supply industry as a whole does not accept responsi-

bility for the providing of means of disposal of stray or waste electric current, water department executives are advised not to order the removal of electrical grounds of alternating current systems from water pipes unless they have been informed by competent legal counsel that such removal order can be supported in the case of court action."

3. *Pipe Line Coefficients.* The activities of this committee continue and a statement from it may be expected at the June meeting.

4. *History of Water Purification.* M. N. Baker, who devotes his time as a labor of love to this project, reports that more than 1,000 typewritten pages have been produced and that he finds yet unexplored other avenues of interest in the subject. His researches have carried him back into the latter years of the 18th Century when plans were emerging (both in France and England) which led to the earliest municipal water treatment plants. It appears advisable to suggest to Mr. Baker that a series of brief résumé statements for the Journal would serve to consolidate general interest in this project.

5. *Basic Data.* This committee coöperated in the development of a list of data to be recorded on all water systems in United States communities. Your secretary has conferred upon a number of occasions with representatives of various governmental departments with the hope that among the many matters into which Federal interest and funds have been directed, this project of a nation-wide fact-finding and recording study of municipal water supplies could be included. The efforts have as yet been non-productive.

6. The Committee on *Ground Water Collection* reports no progress.

7. The *Manual on Quality and Treatment of Municipal Water Supplies* has been edited by Prof. L. V. Carpenter and estimates of publication cost are now being made by various printers. This text will consolidate the best opinion of the leaders in the water treatment field into a manual worthy of Association pride. Paul Hansen and Prof. Lewis Carpenter are to be warmly commended for their services to the water works field in guiding the preparation of the text. It is hoped that the publication will be available for sale by the time of the 1939 convention.

8. The chairmanship of the *Committee on Power and Pumping* has been transferred to Chas. B. Burdick. A complete plan of development and outline of the text has been submitted by Mr. Burdick.

9. The *Steel Plate Pipe* committee specifications have been re-

drafted by Chairman W. W. Hurlbut, following a series of conferences held during the New Orleans convention. The second tentative specifications for electric fusion welded steel pipe, riveted steel pipe and lock-bar steel pipe were distributed by the chairman January 10, 1939. The second tentative specifications for electric fusion steel pipe and protective coatings are completed. It is anticipated that this material will have passed the scrutiny of the subcommittee and the Water Works Practice Committee before the June convention and at that time be ready for consideration by the Board. The chairman has counselled with representatives of the American Welding Society in details relating to welding practice and it is believed that the proposed specifications will adequately represent the best practices in the art of welding.

10. The chairman of the Committee on *Cast Iron Pipe Specifications* (organized under A. S. A. procedure as A21) anticipated in November that he would be able to transmit the document to your secretary for pre-printing prior to this meeting. He has been unable to release the document. When he does so it will be preprinted and copies made available to all A21 members and to the executive boards of the A. W. W. A., N. E. W. W. A., A. S. A., and A. S. T. M. for approval. In order to facilitate publication of the text, your secretary has agreed to assume the cost of printing the document as a part of Journal printing cost. Editorial corrections will be paid for by A21. Eventual publication and distribution of these specifications will be an A. W. W. A. enterprise since the other associations engaged in the work of A21 committee have indicated that they do not wish to join in the funding of publication. Reprints will be sold at only such margin above cost as to liquidate the cost (of type setting and the purchase price of the set type) by the sale of 5,000 reprints and allow a very narrow margin for office expense and mailing.

11. *Gate Valves and Fire Hydrants.* Since the last report to your board, steps have been taken which have resulted in the appointment of a committee from the New England Water Works Association which is responsible for study, suggestions for change and/or recommendations for approval by that association of the specifications for gate valves adopted by your board last April. Likewise a committee has been appointed to review the current text of the specifications for fire hydrants.

Inasmuch as your Board has adopted the gate valve specifica-

tions for promulgation as of May 1, 1939, it will be necessary to publish this material shortly. No comments have been received indicating dissent by the N. E. W. W. A. committee. (On February 16, the N. E. W. W. A. approved the gate valve specifications. See page 502.)

It had been hoped that the hydrant specifications would have progressed far enough for them to be submitted for approval at this meeting. Inasmuch as the N. E. W. W. A. committee is active in its consideration of this material and has planned a discussion of it at the Association meeting on the 19th of this month, it is proper to defer presentation of the text to this board until a later date. Over 200 copies of the text as it now stands have been sent to the heads of water departments in the larger cities and to manufacturers. Few comments have been received. Messrs. Conard, Jensen and Griswold advise a rearrangement of the text. They also have advised increasing the minimum thickness requirement for the hydrant barrel from Class 150 thickness to Class 250 (Federal Specification W. W. P. 421) thickness. This is also proposed by the N. E. W. W. A. committee and seems definitely to be a necessary amendment of the text.

12. The sub-committee on *Meter Specifications* has been fully organized under the chairmanship of Samuel F. Newkirk. A co-operating committee from the N. E. W. W. A., as well as an engineering advisory committee from the water manufacturers has been set up. Definite progress is being made and a preliminary discussion of the proposed revision of the meter specifications will be had at the June meeting.

13. W. V. Weir of the St. Louis County Water Co. has accepted the chairmanship of the Committee on *Distribution System Records* and is organizing his committee. This work is timely since the recently adopted standards of the National Association of Railroad and Utility Commissioners covering fixed property records, retirement units and depreciation methods make it necessary that this committee consider the methods of compliance with these regulations by water works properties and establish as much standard procedure as appears useful.

14. The sub-committees on *Steel Standpipes and Elevated Tanks* and on *Welding of Steel Standpipes, Elevated Tanks and Pipe* operate under the chairmanship of Louis Howson. Following certain conferences during the New Orleans Convention, when it appeared that the adoption (in 1936) of the current specifications for elevated

tanks had not proceeded with adequate consideration of certain issues raised by the manufacturers, the committee was furnished copies of the adverse comments and requested to review the subject fully. This was agreed to by the chairman, who suggested that this review could be combined with the preparation of specifications for welded tanks.

During the year the American Welding Society has made certain representations relating to coöperation between the two organizations in any specifications concerning welding. This, in the case of the elevated tank committee, has been brought about by the appointment of Mr. Howson as the chairman of the A. W. S. Committee on welded water tanks. That committee consists of: L. R. Howson, Chairman, George T. Horton, H. O. Hill, J. O. Jackson, C. W. Obert, H. A. Sweet, and J. P. Schwada, and will work in harmony with the A. W. W. A. Committee on Welding of Standpipes and Elevated Tanks. Its members are: L. R. Howson, Chairman, George T. Horton, J. P. Schwada, H. O. Hill, and J. O. Jackson.

15. The committee on *Distribution System Safety* has not progressed as rapidly as desired. An effort will be made to draw the committee together in conference during the Atlantic City meeting.

16. The committee on *Service Line Materials* has likewise not made progress. There is much for this group to do.

17. The committee on *Transite Pipe* reports no activity.

18. The sub-committee on *Cross-Connections* has been requested to review experiences with the double check and double gate valve method of separation of supplies and to bring up to date the record of progress in control of cross-connections.

19. *Water Purification Division Committees.* The Water Purification Division has established several research and practice committees. The scope of activities of each is reviewed and approved by the Water Works Practice Committee and the reports of such committees, after acceptance by the Division, route to the Water Works Practice Committee for approval. These committees are:

19.1 Specifications and Tests for Water Purification Chemicals
19.2 Activated Carbon Research
19.3 Methods of Testing Zeolites
19.4 Methods of Determining Fluorides
19.5 Chlorine Ammonia Treatment
19.6 Coördinating Committee on Methods of Water Treatment and Laboratory Control

19.7 High Rate Treatment

19.8 Water Conditioning Methods to Inhibit Corrosion

These may be commented upon as follows:

19.1 This project (organized in 1932) has been inactive during the period that the specifications for activated carbon were in preparation. Work has now been resumed.

19.2 This is a new committee, successor to the group that prepared the specifications and tests for activated carbon. That work was published in the July (1938) Journal and has been favorably received by the field.

19.3 A preliminary report was made in 1935. This committee has been asked to prepare a final report for the June, 1939 meeting.

19.4 This committee promises a final report at the June meeting.

19.5 A progress report by this committee is promised.

19.6 This committee is doing highly valuable work. A discussion on obscure intestinal outbursts is scheduled for the Atlantic City meeting. A digest of the recent reports on typhoid at Minneapolis and dysentery at Milwaukee has been made by the committee, widely circulated for discussion and prepared for publication in the Journal. These activities are bringing into open forum many nebulous ideas concerning the responsibility of public water supply for community health disorders. While there is no prospect of standards or specifications or methods issuing as a direct result of the work of this group, a definite contribution to the fundamental value implicit in the organization of the Water Purification Division is being made, since those who join in the discussions now current are led to relate definitely the laboratory control of a water supply with the various treatment processes involved in its production. In recent years, there has not been enough appraisal of this nature.

19.7 The committee on High Rate Treatment is newly organized and no record of its activities is at hand.

19.8 The personnel has been selected for a committee tentatively named "Committee on Water Conditioning Methods to Inhibit Corrosion." W. F. Langelier, of the University of California, is chairman. Its function will be to appraise and promote the application of research related to lessening the corrosivity of water. It will coöperate with the committee on "Pipe Line Friction Coefficients."

20. *Joint Committees with Other Organizations.*

20.1 *Standard Methods for the Examination of Water and Sewage*, now in its eighth edition, a joint enterprise with the A. P. H. A., continues to be recognized as the basic text on laboratory methods

for water control. Few comments have been received indicating that there are sections needing revision. While it had been thought that a new edition would be issued in 1940, at the moment there is not recorded sufficient volume of change to justify the expense involved.

During 1938, the surplus of income over expense of sales totalled $1,995.42. This Association has received $997.71 as its share of the net proceeds.

20.2 The Joint Research Committee on *Boiler Feedwater Studies* (organized in 1925 by Sheppard T. Powell of this Association) continues its activity. Researches concerning embrittlement of boiler steel have been carried on for several years and are now drawing to a close. A review of this work was presented at the New Orleans convention and published in the April (1938) Journal. The general effect of the work of this committee has been highly constructive. The demands upon it are lessening.

20.3 The American Research Committee on *Grounding* has been discussed under item 2.

20.4 The Joint Committee on *Water Works Terms* (A. P. H. A., A. S. C. E. and A. W. W. A.) has had under consideration for about two years a document prepared under Prof. Saville's direction by the Water Resources Committee. The copy of this report which was sent to A. W. W. A. headquarters has been referred to Prof. Lendall, of the New Jersey Section. He and a group of members of that Section have given considerable study to the material. No record of further activity of the committee is at hand.

20.5 The *Manual of Water Works Accounting*, which became available for sale in October, is a very satisfactory document. Two thousand copies were printed and over 500 have already been sold. An agreement has been made with the M. F. O. A. for continuing joint sponsorship of the volume. Surplus from sales of the present text will be earmarked to cover expense of preparing and printing a revised text. The Finance and Accounting Division of this Association will be called upon to nominate three of its members to represent the A. W. W. A. on the joint editorial committee.

20.6 The Inter-Association Committee on *Cross-Connections* (E. S. Chase and M. W. Cowles, A. W. W. A. representatives) should now be liquidated, since A. W. W. A. interest in such matters can be protected by its participation in the reorganized A. S. A. activities relating to Plumbing Safety and Plumbing Codes.

20.7 The Joint Committee on *Water Hammer* was organized prior

to the 1937 symposium on water hammer during the A. S. M. E. annual meeting. No communications concerning this committee have been received during 1938. In order to improve the acquaintance of A. W. W. A. members with this subject, several papers are being scheduled for the Atlantic City convention.

21. *Committees of Other Organizations on Which A. W. W. A. Is Represented*

A. S. A. A21—Reported under item 10
A35—No activity reported
A40—This work is now under investigation by the A. S. A.
B2 —No activity reported
B16—A considerable volume of material is near adoption by this group
B31—No activity reported
B36—No activity reported
C1 —Reported under item 2
G8 —No activity reported
Z23—No activity reported
Z32—No activity reported

A. W. W. A. is represented on four N. F. P. A. committees: Forests; Hydrants, Valves and Pipe Fittings; Public Water Supplies for Private Fire Protection; and Tanks. No activity of any of these groups except the third is reported. A report concerning control of waste from private fire service lines was approved by the committee and adopted by the N. F. P. A.

22. There are pending two requests from the A. S. T. M. The first is that the A. W. W. A. appoint a representative to an inter-association committee to review corrosion control research and methods. The second is that there be appointed a representative to an A. S. T. M. committee on Plastic Sulfur specifications. Both are worth while projects in which the A. W. W. A. has an interest and board approval is requested.

Malcolm Pirnie, *Chairman*,
Committee on Water Works Practice.

January 18, 1939.

Editor's Note: For reference for personnel of the Committee on Water Works Practice, its sub-committees and their scope, see the A. W W. A. Membership List which was issued as a supplement to the July, 1938 Journal.

Hazards of Sulfur Dioxide and Caustic Soda

Committee Report

To the Water Works Practice Committee
of the
American Water Works Association.

YOUR Committee on Chemical Hazards in Water Works Plants begs to report as follows: Attached hereto is the third report of this committee; the first being submitted at the time of the 1935 and the second at the 1936 conventions of the A. W. W. A. The first report presented data and first aid suggestions for chlorine, the second was a similar report for ammonia.

In 1936 this committee asked to be dismissed, deeming its work to be done. At the request of many, this committee has prepared and now submits a third report covering sulfur dioxide and caustic soda.

The great assistance of H. H. Gerstein and L. L. Hedgepeth in the preparation of this report is acknowledged with much appreciation by the chairman. The technical parts have been criticized by most of the manufacturers of these chemicals, and the first aid section was assisted by information from the manufacturers, the Chicago Fire

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A report submitted by the Committee on Chemical Hazards in Water Works Plants. Members of the Committee are: Linn H. Enslow, Editor, Water Works and Sewerage; George H. Fenkell, Supt. and Gen. Mgr., Board of Water Com., Detroit, Mich., H. H. Gerstein, Sanitary Engineer, Dept. Public Works, Chicago, Ill.; Arthur E. Gorman, Engineer of Water Purification, Chicago, Ill., Ray F. Goudey, Sanitary Engineer, Dept. Water & Power, Los Angeles, Calif.; Frank E. Hale, Director of Laboratories, Mt. Prospect Laboratory, New York City; L. L. Hedgepeth, Manager, Tech. Service Dept., Pennsylvania Salt Mfg. Co., Philadelphia, Pa.; Norman Howard, Director of Water Purification, Toronto, Canada; Harold S. Hutton, Sanitary Engineer, Wallace & Tiernan Co., Inc., Newark, N. J.; Willard C. Lawrence, Supt. of Filtration, Cleveland, Ohio; Winfield S. Mahlie, Chemist in Charge, Filtration Plant, Fort Worth, Texas; and M. C. Smith, Engineer in Charge, Bureau of Water & Electricity, Richmond, Va.

Department; National Safety Council; *Toxicology* by McNally; *Noxious Gases* by Henderson and Haggard; Chemical Monograph No. 35, Chemical Catalog Co.; and Technical Paper No. 248, Bureau of Mines, Department of Interior.

Since the last report, the Directors of the A. W. W. A. authorized and instructed this committee to seek action upon the recommendations of this committee seeking the elimination of the fusible plugs from chlorine containers of ton or less capacity, and also to request further study to determine the best type of gas mask.

In January, the Secretary of the A. W. W. A. and the chairman of this committee, in a conference with the Bureau of Explosives, Interstate Commerce Commission in New York, discussed the advisability of omitting fusible plugs from chlorine containers of ton and less capacity. At the advice of this Bureau, the Secretary of the Chlorine Institute was then asked to bring the matter before that organization for its consideration. This has been done but final action has not yet been taken. Certain it is, however, that the action of this committee in recommending the omission of fusible plugs will accomplish its purpose either directly or indirectly—namely the elimination of the cause of accidents due to fusible plugs as the plugs were being used in chlorine containers.

The reports on sulfur dioxide and caustic soda follow:

Sulfur Dioxide

Sulfur dioxide is the product resulting from combining one atom of sulfur with two atoms of oxygen and is usually made by burning sulfur in a stream of air in special burners. The exhaust gases of these burners are first treated to remove from them all impurities including water, dried to a completely anhydrous state, and then by a combination of lowered temperature and increased pressure condensed into the liquid commercial product.

It contains 50.05 per cent sulfur and 49.95 per cent oxygen by weight. Its formula is SO_2; molecular weight, 64.06; melting point, −98.8°F.; boiling point, +14.0°F.; critical temperature, 315°F.; critical pressure, 1141.9 lb. per sq.in. absolute; heat of vaporization, 164.5 B. t. u. per pound at 0°C. Liquid sulfur dioxide is a colorless liquid which at 70°F. exerts 34.6 lb. per sq.in. gage pressure and weighs 86.20 lb. per cu.ft., being 1.38 times as heavy as water.

Liquid sulfur dioxide volatilizes into a colorless gas of pronounced characteristic pungent odor, which gas under standard conditions weighs 2.9269 grams per liter, being 2.2638 times heavier than air.

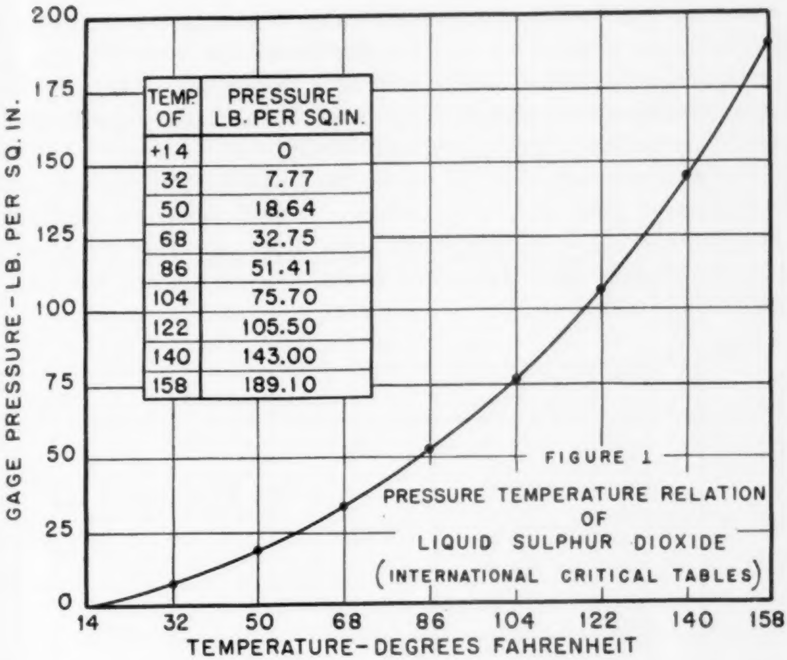


FIGURE 1
PRESSURE TEMPERATURE RELATION OF LIQUID SULPHUR DIOXIDE (INTERNATIONAL CRITICAL TABLES)

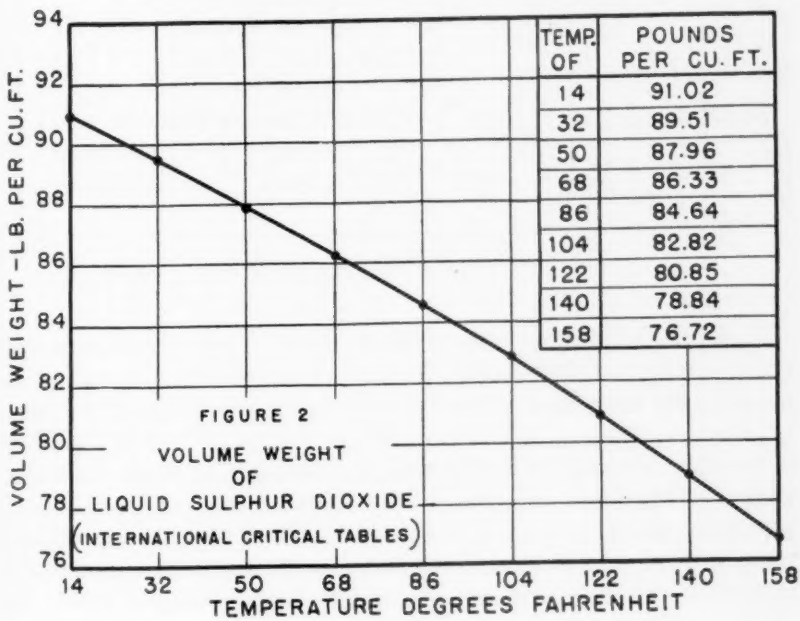


FIGURE 2
VOLUME WEIGHT OF LIQUID SULPHUR DIOXIDE (INTERNATIONAL CRITICAL TABLES)

Neither liquid nor gaseous sulfur dioxide is flammable or explosive. The vapor pressure of liquid sulfur dioxide is shown in fig. 1. Confined in a cylinder, it may exist as a gas, liquid, or both. For all conditions of temperature and pressure whose values meet on this curve, the gas and liquid are in equilibrium.

If the values meet *above* the curve, the liquid is boiling into a gas; if they meet *below* the curve, the gas is condensing into a liquid. This curve, being a vapor pressure curve, does not apply if the container is illegally filled with liquid so that no vapor space is present within the container.

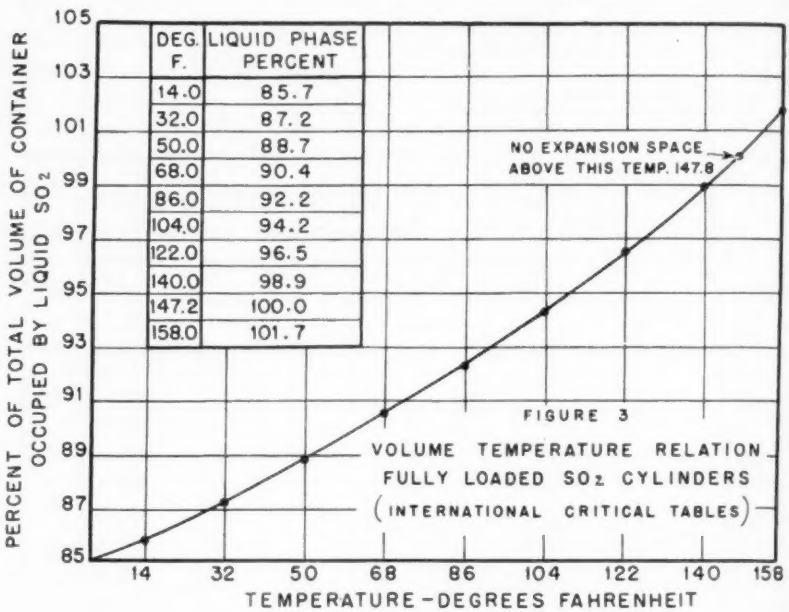
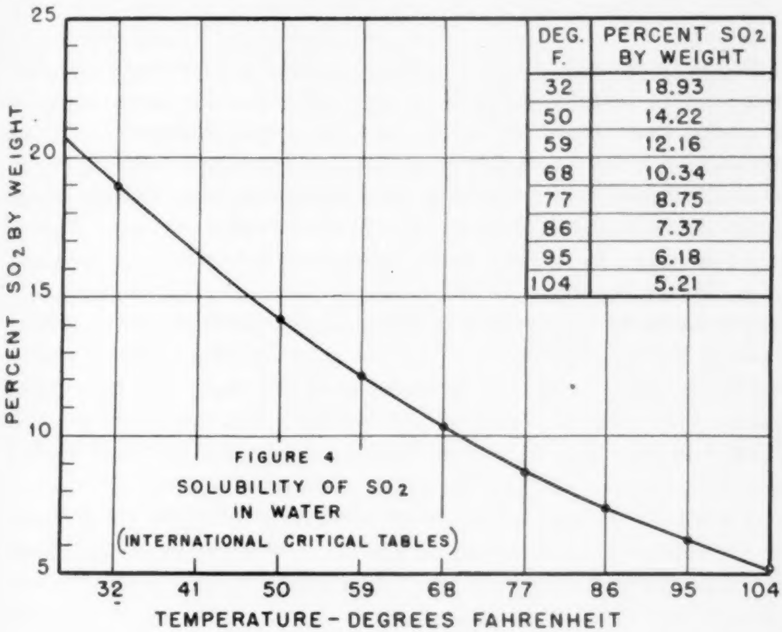


FIGURE 3
VOLUME TEMPERATURE RELATION
FULLY LOADED SO_2 CYLINDERS
(INTERNATIONAL CRITICAL TABLES)

Figure 2 shows the density of liquid sulfur dioxide and fig. 3 the effect of this varying density on any container filled to the legal limit. This legal limit is fixed by the Interstate Commerce Commission for common or contract carrier shipments and is fixed for sulfur dioxide at 125 lb. of sulfur dioxide for each 100 lb. of water the container will hold. Obviously, fully loaded containers will be completely devoid of gas space at temperatures above 147.2°F., and higher temperatures would cause the cylinder to be exposed to dangerous pressures. A relief plug, with a core of metal flowing at 157°F., is

provided in each valve to prevent rupture in case the container is heated to excessive temperatures.

Sulfur dioxide is soluble in water, though not as much so as is ammonia. When sulfur dioxide is mixed with water or moisture, sulfurous acid (H_2SO_3) is formed which is the reason pipelines, tanks, etc. should be kept free of moisture. The solubility of sulfur dioxide in water is indicated in fig. 4.



DEG. F.	PERCENT SO_2 BY WEIGHT
32	18.93
50	14.22
59	12.16
68	10.34
77	8.75
86	7.37
95	6.18
104	5.21

FIGURE 4
SOLUBILITY OF SO_2 IN WATER
(INTERNATIONAL CRITICAL TABLES)

Shipping Equipment Required

Liquid sulfur dioxide is classified as a nonexplosive, noninflammable, compressed gas and is regulated in transit by the Interstate Commerce Commission. It is commonly shipped in steel cylinders, all of which comply with the requirements of the I. C. C. specifications.

Several sizes of containers are available, holding 5 lb., 10 lb., 35 lb., 100 lb., and 150 lb. net each. All are designed for upright storage and operation while in service.

The valves are of two general types: the conventional packed type and the type using no packing, designed especially for the refrigera-

tion trade. *It should be noted* that at this time the valves are not standard; some must be turned clockwise to open while others must be turned counterclockwise. Both types have the fusible plug below the valve seat, which plug should soften at 157°F. and should positively relieve at 165°F. The packing nut on all valves turns clockwise to tighten. Manufacturers strongly recommend that no force be used in operating valves more than is absolutely necessary, using only the handwheel when provided, or a small socket wrench for the stem type.

Dry sulfur dioxide is not corrosive to common metals but *on contact with moisture* it forms sulfurous acid (H_2SO_3) which is quite corrosive to piping and valves ordinarily used for conveying gases. Liquid sulfur dioxide may be safely used in steel or wrought iron piping of the extra heavy type. On long lines a gas expansion chamber may be found necessary in order to prevent hydrostatic rupture. Valves and gages used in the pipe lines (other than container valves) must be designed and packed for sulfur dioxide service. The valves should be substantially constructed of good quality brass and have a deep packing recess. Rubberized asbestos packing (U. S. series 155 or equal) should be used, although one producer uses ammonia valves having lead seats and packed with Garlock No. 150 packing. For flanged joints graphited asbestos seems to be the preferred gasket material, yet lead or even Neoprene is sometimes used.

Attention is called to the special, straight $\frac{3}{4}$-inch pipe thread used on the valves of sulfur dioxide containers. When connection is made to this outlet, care should be taken to see that the connecting threads are suitable and fit in such manner as not to require undue forcing for the connection.

Suggestions for Safe Handling

Compressed gas cylinders are generally safe when intelligently used. Serious accidents are likely to be the penalty of carelessness or ignorant handling. The methods outlined in previous reports for handling other compressed gases in water works plants (Jour. A. W.-W. A., **27:** 1225 (1935) for chlorine and Jour. A. W. W. A., **28:** 1772 (1936) for ammonia) apply also to sulfur dioxide. For emphasis the more important of these former suggestions are here repeated and, in addition, a few suggestions applicable only to sulfur dioxide.

1. Never use lifting magnet, slings or other insecure method for raising containers. Simple apparatus is available (consult supplier)

for conveniently moving containers and for inverting them to permit the withdrawal of liquid sulfur dioxide.

2. Avoid rough handling, and store containers away from elevators and from locations where moving objects may strike or fall against them.

3. Keep containers away from heat. Never store near house radiators, steam pipes, highly inflammable substances; and when in service, warm air is to be preferred for warming containers. This suggestion is to avoid melting the fusible plug.

4. In the event of a leaking container or container valve, remember that sulfur dioxide is relatively soluble in water; hence in emergency the container should be immersed. Alkaline water is most effective. Room ventilation should be designed to remove the air near the floor as the gas will settle rapidly due to the fact that it is more than twice as heavy as air. Water spray will absorb much escaping sulfur dioxide.

5. Masks of the type approved by the U. S. Bureau of Mines for sulfur dioxide should always be readily accessible in places where sulfur dioxide is used.

6. It is unlawful to change numbers or markings on containers, to refill or transfer sulfur dioxide from containers to other containers, or to mix gases in them without the written permission of the owner and the Bureau of Explosives.

7. Open container valves for service, slowly. Operate with as little force as is possible.

8. Hoods should be kept on containers at all times except when in actual service.

9. Empty cylinders should be returned with the lower portion of the shipping tag detached, and they should be classified on bill of lading as "Old sulfur dioxide cylinders (iron, not coppered or nickled) return empty."

Physiological Effects and First Aid Considered

Concentrations of the gas sufficient to cause death are almost irrespirable, therefore, fatal accidents are rare, since persons in a lethal concentration of sulfur dioxide cannot breathe and are compelled to seek the open air. Low concentrations cause a sensation of suffocation, coughing, sneezing, and smarting and lacrymation of the eyes. Liquid sulfur dioxide may cause severe injury to the skin and eyes due to the freezing action caused by rapid evaporation of the liquid.

Physiological responses to various concentrations of sulfur

dioxide (Technical Paper No. 248, U. S. Bureau of Mines) are as follows:

Effect	Parts SO_2 per million parts of Air
Least detectable odor	3–5
Least amount causing immediate irritation to the eyes	20
Least amount causing immediate irritation to the throat	8–12
Least amount causing immediate coughing	20
Maximum concentration allowable for prolonged exposure	10
Maximum concentration allowable for short exposure (½ hr. to 1 hr.)	50–100
Dangerous for short exposure	400–500

Since sulfur dioxide is a lung irritant similar to ammonia and chlorine, the indicated "first aid" treatment for persons affected by this gas is practically the same as that recommended in the committee's report for chlorine and ammonia.

The following suggestions are for the consideration of non-medical persons who wish to help themselves or others who are suffering from exposure to sulfur dioxide, *until the arrival of a physician*, who shall then take charge of the patient.

1. Remove the person affected at once to an atmosphere free of sulfur dioxide fumes. Have patient lie flat on his back in a relaxed position. Keep patient quiet and warm, preventing chilling by wrapping in blankets and using hot water bottles if necessary. Guard against exposure to drafts, especially if patient perspires freely. *Do not excite or exercise patient unduly.*

2. Call a physician.

3. If the patient is unconscious, immediately start using the prone pressure method of producing artificial respiration. If available, call a fire department rescue squad, but be sure that they do not use a pulmotor or other mechanical means of resuscitation, because of the danger of rupturing the lungs of the patient. Administration of oxygen or carbon dioxide mixtures has been successfully used for inducing respiration and relieving coughing.

4. Inhalation of ammonium carbonate fumes relieves respiratory irritation.

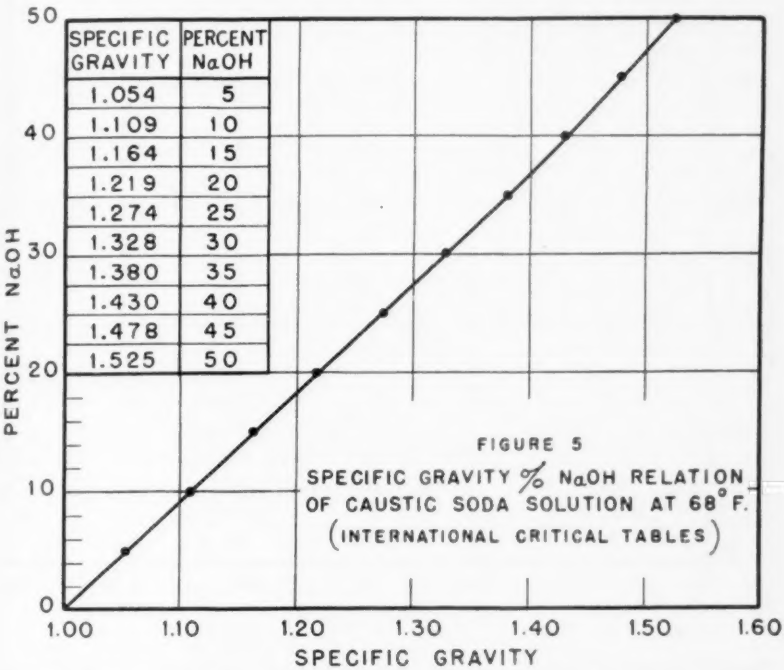
5. Coughing is relieved by drinking the mixture of 3 to 5 drops of chloroform in a full glass of water.

6. For skin freezing and burns from liquid sulphur dioxide, apply water liberally to the affected parts, preferably by placing the patient under a shower. Remove clothing as soon as possible. Moisten sterile dressing in a freshly made up, 5 per cent solution of tannic acid

and apply to burned area. Keep the dressing moist with tannic acid solution, until the burned area attains a dark brown color. Do not allow the tannic acid to come in contact with the inner surfaces of the eyes, as harmful results may follow.

7. For eye irritation or burns, flush the eyes copiously with a gentle flow from a faucet or bubbling fountain. When eyes are thoroughly flushed (5 minutes), allow 2 drops of liquid petrolatum to fall on each eyeball.

8. Irritation of the nose may be relieved by spraying with a bland



SPECIFIC GRAVITY	PERCENT NaOH
1.054	5
1.109	10
1.164	15
1.219	20
1.274	25
1.328	30
1.380	35
1.430	40
1.478	45
1.525	50

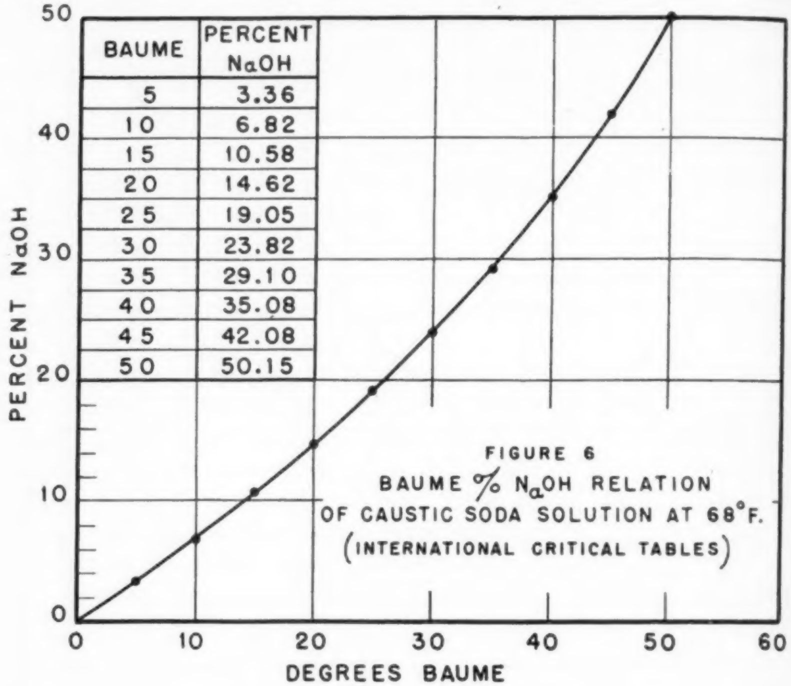
FIGURE 5
SPECIFIC GRAVITY % NaOH RELATION OF CAUSTIC SODA SOLUTION AT 68° F.
(INTERNATIONAL CRITICAL TABLES)

oil, such as liquid petrolatum, or by application of a few drops of ephedrine sulfate in oil into each nostril.

First aid supplies to be kept on hand are: 2 ounces of tannic acid powder U. S. P. fluffy, 2 pint jars of boiled water, 1 package of sterile gauze, and 1 bottle of liquid petrolatum and eye dropper. The 5 per cent tannic acid solution should be freshly prepared by dissolving 8 level tablespoonfuls of tannic acid in a glassful of boiled water. In emergencies where tannic acid powder is not available, a solution may be prepared by boiling four to eight teaspoonfuls of dry tea leaves in one cup of water from three to five minutes. Cool this to body temperature and use as directed above.

Caustic Soda

Caustic soda is a white solid with a fibrous crystalline structure. It is a chemical compound composed of 57.5 per cent sodium, 40.0 per cent oxygen, and 2.5 per cent hydrogen. Its chemical name is sodium hydroxide, formula NaOH, and the melting point 605.1°F. On exposure to the air, caustic soda absorbs moisture and eventually passes into solution in the absorbed moisture. It also combines



BAUME	PERCENT NaOH
5	3.36
10	6.82
15	10.58
20	14.62
25	19.05
30	23.82
35	29.10
40	35.08
45	42.08
50	50.15

FIGURE 6
BAUME % NaOH RELATION
OF CAUSTIC SODA SOLUTION AT 68°F.
(INTERNATIONAL CRITICAL TABLES)

readily with the carbon dioxide in the air and is thus slowly weakened by conversion to sodium carbonate.

Caustic soda is readily soluble in water forming solutions of regular physical behavior. These physical characteristics are useful in determining the strength of the solution. The specific gravity-per cent NaOH relation of caustic soda solution at 68°F. is depicted in fig. 5, and the Baumé-per cent NaOH relation, in fig. 6. The freezing points of various strengths of caustic soda solutions are depicted in fig. 7.

Caustic soda is marketed in the solid, flake, and liquid forms. At

present there is a wide variation in the sizes and the design of the containers in which caustic soda is shipped, each manufacturer having its own standards. Solid caustic is shipped in non-returnable steel drums containing from 700 to 760 lb. of caustic. To remove the caustic soda the drums are cut open usually with an axe, exposing the block of solid caustic.

The flake and ground types are available in drums with removable covers, containing a variety of weights from 25 to 500 lb. each.

Liquid caustic soda is delivered in single unit tank cars of six, eight

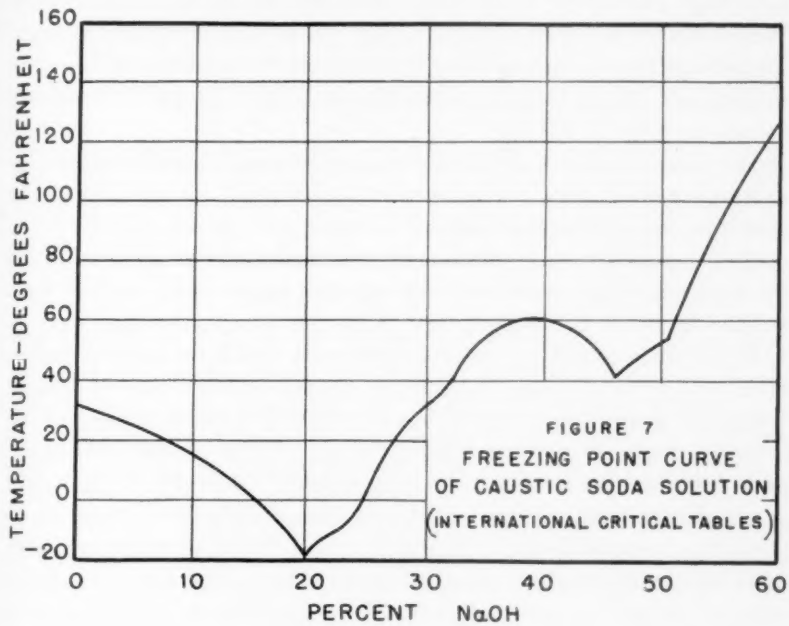


FIGURE 7
FREEZING POINT CURVE
OF CAUSTIC SODA SOLUTION
(INTERNATIONAL CRITICAL TABLES)

and ten thousand gallons capacity. The concentration of the liquid generally sold is 50° Baumé or 49.2 per cent NaOH by weight; and liquids containing 60 or 70 per cent NaOH by weight are also available. Eight thousand gallons of 50° Baumé liquid contains approximately 49,200 lb. of NaOH.

Handling and Storage Require Special Fittings

The solid block of caustic soda is usually dissolved in a known quantity of water making a solution of predetermined strength. By regulating the quantity of this solution added to the water being

treated the desired amount of caustic is obtained. Both flake and ground caustic are dissolved by emptying the contents of a container into the solution water by removing the cover and tilting the drum. Liquid caustic soda, its strength being known, is usually added to the water to be treated without being further diluted.

For transporting concentrated caustic solutions from the dissolving tank or tank car, black iron pipe with cast-iron fittings is suitable. Valves should be of the gate type of cast iron or nickle cast iron, both monel trimmed. If pumping is necessary, a pump with cast-iron body and monel metal shaft, impeller and glands is preferable. When lines must be out of doors, they should be heated by a steam line alongside the caustic line and the two wrapped with suitable insulation. When not in use the line should be purged with air (or steam) to prevent freezing.

For more dilute solutions (less than 50° Baumé) black iron fittings and pipe are suitable, and gate valves may be of cast iron or nickle cast iron, and asbestos packed.

The storage tanks for liquid caustic soda and the solution tanks for dissolving solid caustic are best made of heavy plate steel, of fuse-welded or riveted construction if joints are absolutely tight.

It should be noted that solid caustic soda rapidly absorbs moisture from the air and hence containers should be kept tightly closed. Solution and storage tanks should also be well covered to prevent the absorption of carbon dioxide from the air. Since 50° Baumé caustic soda freezes at 50°F. or less, forming crystal $NaOH \cdot 2H_2O$, the tanks must also be kept warm at all times, steam coils with steam at 15 lb. or less being necessary if tanks are exposed to lower temperatures. However, care must be taken to avoid heating the caustic soda to more than 125°F. If it is necessary to keep the iron content to a minimum, these tanks may be painted with a caustic soda resistant paint.

The following suggestions are included to indicate some of the problems involved to aid water works engineers who plan to use liquid caustic soda. They should determine the details of the cars to be used, as a wide variation exists in car connections and design. The best method of unloading tank cars requires expert study for each location, in which the supplier will be glad to assist.

Steam must be available for, if the car is received frozen, the steam coils in the car will have to be used. As previously stated, the steam pressure should not exceed 15 lb. As a general word of caution,

in times of very cold weather a crust may form on the top of the liquid. When this is true, a large hole should be broken through the crust before applying steam to allow for the expansion. *The dome must always be open* when unloading.

Caustic soda is a corrosive chemical and will rapidly destroy clothing, particularly woolen fabrics and leather shoes. In contact with the human skin, serious injury may result before the person is aware of it, since there is often no immediate warning of its presence by stinging. Therefore, the workmen handling it should wear goggles, rubber gloves, boots, and rubber aprons.

If one is accidently burned with caustic, flush the affected part with a large amount of water followed by dilute acetic acid or vinegar. The application of tannic acid powder following the flushing is helpful.

If caustic solution is splashed in the eyes, wash repeatedly with water followed by boric acid solution using an eye cup. Liquid petrolatum drops in the eyes may be used after washing. Do not fail to visit a physician promptly, when the eyes are injured by caustic soda.

Personnel of the Committee on Chemical Hazards in Water Works Plants

LINN H. ENSLOW
GEORGE H. FENKELL
H. H. GERSTEIN
ARTHUR E. GORMAN
RAY F. GOUDEY
FRANK E. HALE
L. L. HEDGEPETH
NORMAN HOWARD
HAROLD S. HUTTON
WILLARD C. LAWRENCE
WINFIELD S. MAHLIE
M. C. SMITH

Submitted by M. C. SMITH, *Chairman*

Specifications for Gate Valves For Ordinary Water Works Service

Effective May 1, 1939

A SPECIFICATION ADOPTED JOINTLY
BY THE
AMERICAN WATER WORKS ASSOCIATION
AND THE
NEW ENGLAND WATER WORKS ASSOCIATION

Approved by the A. W. W. A. Board of Directors April 28, 1938*
Approved by the N. E. W. W. A. Executive Committee
February 16, 1939

Table of Contents

*** See note at end of text.**

Section 1—Type of Valve and Character of Service

1.1 These specifications embrace hand-operated, inside-screw, iron body, bronze mounted gate valves of both the "double disc" and "solid wedge" type, ranging in size from 3 inches to 48 inches in diameter, for ordinary water works service in approximately level setting under operating pressures not exceeding 150 lb. per sq.in.

1.2 These specifications make no provision for the requirements of special conditions of installation or operation, such as:

Power drive;
Installation in vertical or steeply inclined pipe lines;
Water of unusually corrosive quality;
Very frequent operation—as in filter service;
Service in throttled position;
Uniform very low pressure;
Excessive water hammer.

1.3 Such conditions, as well as operating pressures and types and sizes of valves which are outside of the stated limits, are beyond the intended scope of these specifications and will in each case require special consideration in matters of design and construction.

Section 2—Supplementary Details to Be Specified

2.1 In purchasing valves under these specifications, it will be necessary to make supplementary specific statement as to the requirements concerning the following details:

2.11 Type of gate valve desired—double disc or solid wedge.

2.12 Type of body ends desired; if bells or flanges of dimensions other than those specified in Sects. 9 and 10, or if other special type of body ends are desired, give substitute specification in full;

2.13 Special uses of bronze, as may be desired;

2.14 Direction in which the wrench-nut shall turn to open valve—whether right (clockwise) or left (counterclockwise);

2.15 Wrench-nut—if dimensions are required different from those specified in Sect. 20, state them in full detail;

2.16 Geared Valves—call for valves to be provided with gears as desired, and state whether horizontal stem

with bevel gears or vertical stem with spur gears is required;
(Without further explicit statement, cast-iron gears will be furnished as specified in Sect. 21).
Call specifically for the following features, if they are desired:
Encased Steel Gears (See Sect. 22);
Indicator (See Sect. 23);

2.17 By-passes—for valves 16 inches in diameter and larger state whether by-passes are required or not (See Sect. 24);

2.18 Special markings—if purchaser's initials or other special markings are to be cast on the body or bonnet, so state (See Sect. 27);

2.19 Specify drawings and statement of weights, if required (See Sect. 3).

Section 3—Data to Be Furnished by the Manufacturer

3.1 The manufacturer shall furnish catalog data, including illustrations and a schedule of parts and the materials of which they are made, in sufficient detail to serve as a guide in the assembly and taking down of the valve and in ordering repair parts.

3.2 When required by supplementary specifications, the manufacturer shall furnish a statement giving the total net assembled weight for each size of valve; and when required shall furnish drawings of adequate size showing the principal dimensions, kind of material and finish of all parts.

Section 4—Size of Waterway

4.1 With the gate open, each valve shall afford an unobstructed waterway of diameter not less than the full nominal diameter of the valve.

Section 5—Basis of Structural Design

5.1 All parts of all gate valves shall be designed to withstand, safely and without permanent distortion, both the stresses resulting from an internal test pressure of 300 lb. per sq.in., and the combined stresses resulting from the full internal service pressure of 150 lb. per sq.in. coincident with the moving of the valve gates across their seats in either direction under full unbalanced service pressure from their fully closed position to the point of opening.

5.2 Further, the valve case and the internal parts of all valves shall be so constructed as to develop the full strength of the valve stem to the point of failure, in moving the valve gates in either direction across their seats from the point of opening to their fully closed position under full service pressure, without rupture or permanent deformation of any other part.

5.3 The provisions recorded in Sects. 5.1 and 5.2 above govern the structure and dimensions of any gate valve purchased under this specification.

TABLE 1

Minimum Thickness of Bodies and Bonnets

DIAMETER OF VALVE	MINIMUM THICKNESS	DIAMETER OF VALVE	MINIMUM THICKNESS
inches	*inches**	*inches*	*inches**
3	0.37 ($\frac{3}{8}$)	20	0.97 ($\frac{31}{32}$)
4	0.40 ($\frac{13}{32}$)	24	1.08 ($1\frac{1}{12}$)
6	0.43 ($\frac{7}{16}$)	30	1.39 ($1\frac{13}{32}$)
8	0.50 ($\frac{1}{2}$)	36	1.54 ($1\frac{17}{32}$)
10	0.63 ($\frac{5}{8}$)	42	1.58 ($1\frac{19}{32}$)
12	0.68 ($\frac{11}{16}$)	48	1.73 ($1\frac{23}{32}$)
16	0.85 ($\frac{27}{32}$)		

* The decimal fraction governs whenever the two expressions are not exactly equivalent. The figures listed are taken from the pending (1939) A. S. A. Specifications for cast-iron pipe. Thicknesses up to and including 36-inch valves are the same as those specified for Class 250 pit cast pipe. Thicknesses of 42-inch and 48-inch valves are the same as those specified for Class 200 pit cast pipe.

Supplementary and subordinate thereto, there is appended herewith a table of minimum thicknesses for valve bodies and bonnets. Valve bodies and bonnets shall be cast so that the metal at any point is not thinner than the minimum specified in table 1 for the particular sized valve under consideration.

Section 6—Iron Castings

6.1 The body, bonnet, gates, and other parts as specified shall be cast from a superior quality of iron remelted in a cupola, or in an air or electric furnace, producing a metal which is tough, of uniform fine grain, without chilled surfaces, readily machined and conforming with the standard specifications of the American Society for Testing

Materials, Serial Designation A 126–30, or revisions thereof. Valve bodies and bonnets 10-inch and larger shall conform to Class B material. All castings shall be clean and sound, without defects of any kind; no plugging, welding or repairing of defects will be allowed.

6.2 From each heat of metal, the manufacturer shall make and test without charge, two deflection test bars, and two tension test bars.

Section 7—Bronze

7.1 All gate valve parts requiring special ability to resist corrosion or requiring smooth surfaces in order to minimize friction, shall be made of bronze or bushed or faced with bronze or other suitable approved non-corrodible metal. This includes stems and stem nuts, thrust bearings, packing glands, gear spindles, gate and body rings, wedging devices, guides, rollers and tracks, and indicator mechanisms, all as hereinafter specified in detail.

7.2 All bronze parts shall be made of metal of known and approved composition.

7.3 Valve stems and stem collars and stem nuts shall be cast or forged from manganese bronze or other suitable approved non-corrodible metal having a tensile strength of not less than 60,000 lb. per sq.in., a yield point of not less than 30,000 lb. per sq.in. and an elongation of not less than 15 per cent in 2 inches, for 3-inch to 24-inch valves (inclusive). For valves of sizes 30-inch to 48-inch (inclusive), the stem metal shall have a tensile strength of not less than 80,000 lb. per sq.in., a yield point of not less than 40,000 lb. per sq.in. and an elongation of not less than 15 per cent in 2 inches.

7.4 Bronze alloy for peened or rolled-in gate rings shall be sufficiently malleable to conform to dovetailed grooves and shall have a minimum compressive strength, without deformation, of 4,000 lb. per sq.in.

7.5 Bronze alloy for other valve parts shall have a tensile strength of not less than 30,000 lb. per sq.in., a yield point of not less than 14,000 lb. per sq.in. and an elongation of not less than 15 per cent in 2 inches.

7.6 The manufacturer shall make and test not less than one test bar from each heat of metal, in accordance with the American Society for Testing Materials specification for the material used.

7.7 All bronze facings and bushings shall be of ample dimensions.

Section 8—Workmanship

8.1 All foundry and machine work shall be done in accordance with the best modern practice for the class of work involved.

8.2 All parts shall conform accurately to the required dimensions and shall be free from injurious defects. All machined parts shall be made to template or gage.

8.3 All joints shall be faced true and shall be water-tight where subject to water pressure.

8.4 The bolt holes of the cast-iron flanges and flanged fittings need not be spot faced for ordinary service except as follows: In sizes 12-inch and smaller, when rough flanges, after facing, are over-size more than $\frac{1}{8}$ in. in thickness, they shall be spot faced to the specified thickness of flange (minimum) with a plus tolerance of $\frac{1}{16}$ in. In sizes 14- to 24-inch inclusive, when rough flanges, after facing, are oversize more than $\frac{3}{16}$ in. in thickness, they shall be spot faced to the specified thickness of flange (minimum) with a plus tolerance of $\frac{1}{16}$ in. In sizes 30-inch and larger, when rough flanges, after facing, are oversize more than $\frac{1}{4}$ in. in thickness, they shall be spot faced to the specified thickness of flange (minimum) with a plus tolerance of $\frac{1}{8}$ in.

8.5 All iron parts receiving bronze mounting shall be made true and smooth and the bronze mounting shall be finished to fit.

8.6 Such hand work shall be done in finishing as is required to produce a neat, workmanlike, well-fitting, and smoothly operating job throughout.

8.7 All parts of valves of the same size and same make shall be interchangeable.

Section 9—Bell Ends

9.1 The dimensions of the sockets of bell-end gate valves shall conform to the dimensions for "Class C" special castings as required in the American Water Works Association Standard Specifications for Cast-Iron Pipe and Special Castings, up to and including 24-inch, unless explicitly otherwise provided in supplementary specifications. Sizes 30-inch and larger shall be as specified.

9.2 The thicknesses and disposition of metal in the bells shall be such as to produce strength not less than that of bells of "Class D" dimensions under the same Standard Specifications.

Section 10—Flanged Ends

10.1 The end-flanges of flanged end gate valves shall conform in dimensions and drilling to the "American 125 lb. Cast-Iron Flange Standard" as promulgated by the American Standards Association, unless explicitly otherwise provided in the supplementary specifications.

Section 11—Bodies and Bonnets

11.1 Valve bodies and bonnets shall be made of cast iron, ruggedly constructed for resistance to distortion under all operating and test conditions.

11.2 It is recognized that some variations are unavoidable in the making of patterns and castings. In order to define what may be considered a reasonable degree of accuracy in shell thickness measurements, the following inspection limits shall be allowed: shell thickness measurements taken at points diametrically opposite shall, when added together and divided by two, equal or exceed the minimum metal thicknesses given in the drawings. Shell thicknesses at no point shall be more than $12\frac{1}{2}$ per cent below the minimum metal thicknesses called for in the drawings, and no continuous area of deficient thickness shall exceed $12\frac{1}{2}$ per cent of the superficial area of the casting.

11.3 The necks of all flanges shall be thickened, ribbing shall be properly proportioned, and corners shall be coved and rounded, in accordance with the best foundry practice.

11.4 Threads in bodies shall be accurately cut and of ample depth to secure the seat rings, and the seats shall be machined to fit the backs of the rings.

11.5 The thrust bearing recess and the stem opening in the bonnet shall be finished. In valves 16 inches in diameter and larger, the thrust bearing recess shall be bronze lined, and the stem opening shall be bronze bushed.

11.6 In horizontal stem valves 16 inches in diameter and larger, and in vertical stem valves 24 inches in diameter and larger, a pair of accurately matched dowel holes and tapered or round-end dowels shall be provided in the flanges of body and bonnet to aid in assembling. Dowels shall be located at opposite ends of the flange, one on the lateral center line and the other about two inches therefrom.

Section 12—Gates

12.1 Gates may be of the "double disc parallel seat," "double disc inclined seat," or "solid wedge" type.

12.2 In valves 3 inches in diameter and smaller, the entire gate assembly shall be made of solid bronze. In larger valves, the gates shall be made of cast iron unless bronze is explicitly required by supplementary specifications.

12.3 Gates shall be ruggedly constructed for resistance to deflection.

12.4 Cast-iron gates shall be accurately machined to receive the bronze gate rings. Where gate rings are to be rolled, peened or pressed in, the grooves receiving the ring metal shall be machined.

Section 13—Gate and Body Rings

13.1 Gate and body rings shall be made of cast bronze, with cross-section sufficiently stiff to resist accidental deformation in handling and assembly.

13.2 Body rings shall be back-faced, the threads accurately cut, and the rings screwed into machined seats in the body.

13.3 Gate rings shall be rolled, peened or pressed into grooves machined in the gates.

13.4 Finish cuts shall be taken over the gate rings after they are finally secured in place.

13.5 The width of body rings shall be sufficient to result in a bearing pressure of gate on the body ring of not more than 2,000 lb. per sq.in. under the hydrostatic pressure of 300 lb. per sq.in. The thickness of the body ring shall not be less than 20 per cent of the actual width of the face.

13.6 The width of face of the gate rings shall be not less than that of the seat rings, and such greater width shall be provided as is practically required in order that the gates may continue to seat tightly after allowing for reasonable wear of the faces of the rings and of the various parts of the mechanism of the gate.

Section 14—Wedging Device

14.1 Gate valves of the "double disc parallel seat" type shall be equipped with an internal wedging device which, in closing the valve will operate, when the gates reach position opposite the ports, to spread the gates apart and press them firmly against the seats. The

mechanism shall be so constructed that it will release with the first half-turn of the stem in starting to open the valve.

14.2 The wedging device shall be simple and rugged in design and shall operate freely and positively with the valve in normal position, both in wedging the gates into contact with the seats and in releasing them therefrom.

14.3 In valves 3 inches in diameter and smaller, the entire wedging mechanism between the discs shall be made of solid bronze.

14.4 In valves 16 inches in diameter and larger, all wedging surfaces shall be bronze to bronze or other approved non-corrodible metal; in valves of diameter from 4 inches to 12 inches, inclusive, wedging surfaces may be bronze or other approved non-corrodible metal to iron.

14.5 Pins and bolts in the wedging mechanisms of all valves shall be made of bronze or other suitable approved non-corrodible metal.

Section 15—Guides

15.1 In solid wedge gate valves, tongue-and-groove guides shall be provided on the sides of the gate and in the case, to keep the gate centered between the seats throughout its full length of travel. In valves 16 inches in diameter and larger, bearing of gate on guides shall have length equal to 50 per cent of port diameter of valve. Guide contacts shall be bronze to bronze.

15.2 In double disc gate valves, the case shall be filleted to reduce the side clearance of the gates.

Section 16—Rollers and Tracks for Horizontal Valves

16.1 Gate valves *of double disc type*, 16 inches in diameter and larger, designed *to lie horizontally in a horizontal pipe line*, shall be equipped with solid bronze or hard babbitt tracks securely fastened in body and bonnet carrying the weight of the gates throughout their entire length of travel on rollers or shoes.

16.2 In solid wedge gate valves, the tongue-and-groove gate guides specified in Sect. 15 may be modified to serve this purpose also.

16.3 In double disc gate valves of the "rolling disc" type, the discs will serve as rollers, operating on bronze or hard babbitt tracks.

16.4 In double disc gate valves of other design, the discs shall be carried on solid bronze rollers securely attached to them, except that in valves 16 inches in diameter bronze shoes may be used instead of rollers.

16.5 In all valves in which rollers are used, bronze scrapers shall be provided to traverse the tracks ahead of the rollers in both directions of travel, removing any foreign matter which may have accumulated on the track.

Section 17—Stems and Stem Nuts

17.1 Valve stems and stem nuts shall be cast or forged or rolled and forged from manganese bronze, or other suitable non-corrodible metal having physical qualities which meet the requirements specified in Sect. 7. Stem collars shall be cast or forged solid with the stems.

17.2 The threads of stems and stem nuts shall be of the square, Acme, modified Acme or ½ V type, cut with a sufficient number of cuts to avoid straining the metal.

17.3 Stems shall be turned and threaded straight and true, and shall work true and smooth and in perfect line throughout the lift of opening and thrust of closing the valve.

17.4 The diameters of stems at base of thread and number of threads per inch for determining pitch shall be not less than as shown in table 2.

Section 18—Thrust Bearings

18.1 Thrust bearings shall be designed to develop safely the full strength of the valve stem. The housing for the thrust bearing shall be carefully machined, and in valves 16 inches in diameter and larger, shall be bronze lined.

Section 19—Stuffing Boxes

19.1 Stuffing boxes shall be made of cast iron, with stem opening, thrust bearing recess and bonnet face carefully machined. In valves 16 inches in diameter and larger, the stem opening shall be bronze bushed, and the thrust bearing recess shall be bronze lined.

19.2 Stuffing boxes shall have depth not less than the diameter of valve stem to be passed, and internal diameter adequate to receive sufficient packing to insure no leakage.

19.3 Glands for valves 12 inches in diameter and smaller shall be made of solid bronze; for larger valves, glands may be made of cast iron with bronze bushings.

19.4 Gland followers, where used, may be made of cast iron.

19.5 Gland bolt nuts shall be made of bronze of the same quality as the stem metal; bolts shall be rolled and forged or cast.

19.6 Stuffing boxes shall be packed with best quality soft graphited or oiled hydraulic packing, made of flax of medium fiber length or of properly lubricated braided asbestos.

Section 20—Wrench-Nuts

20.1 Wrench-nuts shall be made of cast iron, fitted to the top of the valve stem and secured by nut or key.

20.2 Except as explicitly otherwise provided in supplementary specifications, the wrench-nuts shall be $1\frac{15}{16}$ inches square at the top, 2 inches square at the base, and $1\frac{3}{4}$ inches high, with a flanged base upon which shall be cast an arrow at least 2 inches long showing the direction of opening and the word "OPEN" in distinct $\frac{1}{2}$ inch letters.

TABLE 2

Minimum Number of Threads per Inch

DIAMETER OF VALVE	MINIMUM DIAMETER OF STEM AT BASE OF THREAD	MINIMUM NUMBER, THREADS PER INCH
inches	*inches*	
3	0.8594	3
4	0.8594	3
6	1.00	3
8	1.00	3
10	1.125	3
12	1.188	3
16	1.438	3
20	1.75	3
24	1.969	2
30	2.188	2
36	2.50	2
42	2.75	2
48	3.50	2

Section 21—Cast-Iron Gears

21.1 Except as otherwise explicitly required by supplementary specifications, geared valves shall be equipped with gears made of cast iron of the quality specified in Sect. 6, accurately formed and smooth running, with bronze spindles running in bronze or babbitt lined bearings of ample size.

21.2 Gearing shall be designed for maximum facility and speed of operation with a minimum number of men.

Section 22—Encased Steel Gears

22.1 When steel gears are explicitly called for by supplementary specifications, geared valves shall be equipped with machine cut cast steel gears, accurately formed and smoothly finished, with bronze spindles running in bronze or babbitt lined bearings of ample size enclosed in oil-tight cast-iron gear case mounted on brackets attached to the bonnet of the valve in such manner as to permit repacking the stuffing box of the valve without disassembly.

TABLE 3

Gear Ratios

DIAMETER OF VALVE	GEAR RATIO
inches	
16	2:1
20	2:1
24	2:1
30	3:1
36	3:1
42	4:1
48	4:1

TABLE 4

Size Requirements of By-passes

DIAMETER OF VALVE	DIAMETER OF BY-PASS
inches	*inches*
16–20	3
24–30	4
36–42	6
48	8

22.2 Steel gearing shall be designed for maximum facility and speed of operation with a minimum number of men, and gear ratios shall be not less than those shown in table 3.

22.3 Steel castings shall meet the requirements of the Standard Specifications of the American Society for Testing Materials, Serial Designation A-27-24* for carbon steel castings, Class B, soft, except that the sulfur content shall not exceed 0.05 per cent.

* This specification has been revised and is now in tentative form with serial number A-27-36 T.

Section 23—Indicators

23.1 When required by supplementary specifications, geared valves shall be equipped with indicators to show the position of the gates in relation to the ports. The indicator mechanism shall be made of bronze or other non-corrodible metal throughout, mounted in a heavy dirt-proof cast-iron case.

Section 24—Bypasses

24.1 Bypasses when required shall be of the sizes shown in table 4.

Section 25—Gaskets

25.1 Water-tight flanged joints shall be made up with suitable gaskets, full cut with holes to pass bolts or cut to fit inside bolts. Gasket material shall be free from corrosive alkali or acid ingredients.

Section 26—Bolts and Nuts

26.1 All bolts and nuts shall be American Standard, and, except as otherwise specified, shall be made of steel conforming with the Standard Specifications of the American Society for Testing Materials, Serial Designation A 107-36 for carbon open hearth hot rolled bar steel, and shall be rust-proofed by galvanizing, Parkerizing, Sherardizing, or other approved process.

26.2 Bolts and nuts shall be "semi-finished" when bearing is on finished surfaces.

Section 27—Cast Markings

27.1 Each valve shall be plainly marked with the manufacturer's name or particular mark, and with the year it was made, the size of the valve, and the designation "150 W" indicating the working water pressure, all cast on the bonnet or body.

27.2 When required by supplementary specifications, special markings to the number of not more than four additional letters or figures shall also be cast thereon.

Section 28—Painting

28.1 All ferrous parts of the valves, except finished or bearing surfaces, shall be given two coats of asphaltum varnish or pipe dip. After the valves are assembled and tested a third coat shall be applied on the exterior.

Section 29—Testing

29.1 After completion, each gate valve shall be tested at the shop for performance in operation, and for water-tightness and resistance to distortion under internal pressure.

29.2 Each valve shall be operated, in the position which it will assume in service and for the full length of gate travel in both directions, to demonstrate the free and perfect functioning of all parts in the intended manner; any defects of workmanship shall be corrected and the test repeated until satisfactory performance is demonstrated.

29.3 Each valve shall be subjected to hydrostatic tests under pressures of both **300** and **100** lb. per sq.in. The tests shall be conducted in the following manner:

29.31 For solid wedge gate valves—the hydrostatic pressure shall be applied through bulkheads alternately to the two sides of the closed gate with the opposite side open to inspection, and again with both ends bulkheaded and the valve open.

29.32 For double disc gate valves—the hydrostatic pressure shall be applied inside the bonnet with gates closed.

29.4 Under the **300** lb. test there shall be no leakage through the metal or permanent deformation of any casting. Under the **100** lb. test all joints and seats shall be perfectly water-tight.

Section 30—Inspection

30.1 All work under these specifications shall be subject to inspection and approval by the purchaser's duly authorized engineer or inspector, who shall at all times have access to all places of manufacture where materials are being produced or fabricated or tests are being conducted, and shall be accorded full facilities for inspection and the observation of tests. Any gate valve or part which he may condemn as not conforming to the requirements of these specifications shall be made satisfactory or shall be rejected and replaced.

Section 31—Preparing for Shipment

31.1 Gate valves shall be complete when shipped, and the manufacturer shall use all due and customary care in preparing them for shipment so as to avoid damage in handling or in transit. Particular care shall be taken to see that all valves are completely closed before

shipment. Valves 24 inches in diameter and larger shall be securely bolted or fastened to skids in such manner that they may be safely unloaded with a crane.

NOTE: These Specifications supersede specifications adopted June 24, 1913 and modified June 9, 1916.

The A. W. W. A. Committee to revise the 1916 Specifications was appointed December 7, 1929. The first draft of the committee report was issued on April 8, 1931. After a series of conferences and various revisions of the original draft, the report was, on January 22, 1937, approved as a tentative specification and ordered printed.

The tentative specification appeared in the March, 1937 issue of the Journal of the A. W. W. A. It was re-edited as of April 5, 1938, approved by the Water Works Practice Committee on April 25 and adopted by the A. W. W. A. Board of Directors on April 29, 1938.

It was transmitted to the New England Water Works Association with a request for approval by that body. Following a report by a special committee, the Executive Committee of the N. E. W. W. A. approved the Specifications on February 16, 1939.

The Specifications are effective as a basis of purchase on May 1, 1939.

Physical Property Records

By Harold B. Gotaas

THE physical property record, as the name signifies, is an account or record of information concerning a unit of physical property or a group of similar units which may be combined for record purposes and accounted for as a unit of property. The record should contain the pertinent information about the property unit that is essential in the management of the enterprise in which the unit has a function. This information includes such data as the description of the unit, its location, expected life, depreciation, repairs, and maintenance and operation data.

Property records are in general concerned with operating equipment, machinery, buildings and other property with whose characteristics the plant superintendent, engineers, operators, and others concerned with operations are most familiar. Since to keep an adequate record of specific property a thorough understanding of that property is necessary, the people most familiar with the property should be responsible for furnishing the data. Property record accounting requires that the accounting staff and the operating staff combine their efforts in a common cause.

It is difficult, if not impossible, to handle adequately problems of capital accounts, repairs and maintenance, depreciation, retirement and replacement, and operation costs without a system of property records. Accountants in meeting the responsibility of maintaining a record of cash transactions, cash receipts and disbursements, have developed procedures with breakdowns and sub-accounts so that water works and sewage works funds are accounted for to the last cent. The property records are concerned with conditions and changes in the capital assets, such as ordinary depreciation, functional

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depreciation, retirements and replacements, which are not yet reflected in the cash transactions. Water and sewage works like many other businesses process a raw material into a finished product and, hence, should be able to analyse the various costs which contribute to the total cost of supplying a safe and potable water in the case of a water works, or the cost of collecting and treating sewage in the case of a sewage works.

Capital accounts covering all items of property are essential since water and sewage works deal daily with changes in capital assets. Each time a new service is put in, a meter installed or a sewer extended the capital account is increased. Likewise, when a service or a meter is abandoned, the capital account is decreased. The property records provide a *continuous inventory* with a complete history and a full description, always up to date, covering each important property item. The record of an item of property should where possible include more than the expenditure in just dollars and cents total; it should show in what the money was invested. For example, the property record in the case of a clarifier should show the cubic yards of excavation and its costs, concrete and its costs, and the machinery with its cost.

Itemized Records Form Base for Estimates

Building up a property inventory and recording property data may be divided into two main sections: that pertaining to existing property and that pertaining to new construction. The task regarding existing property is often somewhat difficult since in many cases only personal recollection is available for the determination of certain facts about the property. In some instances, the approximate cost and value of items may be obtained from manufacturers and supply houses. Often the property record data can be obtained only by estimation. Property record data for future construction implies a more detailed record and will in most cases be obtained from the contract costs or from work orders and purchase orders where the property is constructed by the municipality or utility; with only little additional effort the costs may be itemized. Such records provide a reliable source of unit costs for future estimates.

The *rate* to be charged for a service sold by a revenue producing business, such as a water works, depends upon plant values together with depreciation and operation expenses. The Supreme Court has held that rates must be based upon the value of the property devoted

to the service. Without a record of the changing value of the capital assets it is difficult, if not impossible, to determine what profit the plant is earning. In the case of municipal plants which do not desire to earn a profit, the records are necessary to determine if the investment in the plant is being maintained by those who use the service.

Depreciation in water works is a considerable item in the operating expense, due to the large fixed investment. Annual depreciation is often computed by assuming some more or less arbitrary composite percentage of the property value as the annual depreciation for the entire plant, rather than by applying an annual depreciation percentage (arrived at from mortality data) to each item or group of like items of property. An arbitrary composite depreciation does not solve the problem of depreciation, accurately protect the investment in the plant, or provide detailed and reliable depreciation information for rate-making. The property record serves as an efficient tool for depreciation accounting, in that an analysis is made of each unit or group of similar units based upon their use, value and longevity, and depreciation is computed for each unit or group making use of depreciation experience for that type of property.

Data on Mortality of Equipment Is Lacking

The more modern mechanization of water and sewage works has introduced many changes in the depreciation and maintenance aspects of water and sewage works operation and management. There is a decided shortage of reliable data on the mortality of water and sewage works equipment. Engineers, public service commissions and taxation bureaus have published information on the service lives of specific units of property. However, this information is limited in its scope. Adequately kept property records will provide much needed information on the service lives of equipment as well as repair and maintenance data. This information is not only valuable to the operation of plants but also to the engineers who make an economical selection of water and sewage works equipment.

The property record form may be designed to include cost data concerning repairs and maintenance as well as data on the input and output and a record of the time used for specific equipment. These data when analysed with the depreciation will permit a comparison of the operation costs for different equipment performing about the same functions, and thereby a more judicial selection of equipment is possible. Cost data, on the various operations in plants

designed for flexibility, provides information for the choice of the most economical arrangement of operations to obtain the desired results. Property record cost data will indicate at what time it is cheaper to install a new unit of equipment than to pay large maintenance and repair costs on the old unit.

Other purposes served by property records are as follows: (1) Detailed information is available for supporting the general ledger of the water or sewage works; (2) A record of property for insurance and taxing purposes is available; (3) The accuracy of accounting is increased; (4) Records of the property are available in case part of the works are destroyed by a disaster; and (5) Dependable information is available for budgetary purposes.

Property Record Forms Considered

The loose leaf book or card system is usually most suitable for the property record file since only those pages or cards which are necessary for current work need be kept in the file and additions may be made whenever they are required.

The property record form should be designed so as to provide accuracy, brevity, and compactness and still obtain the necessary amount of detail. There is a limit to the amount of detail that should be included in property records. However, all pertinent facts about a unit of property from the time of acquisition to the time of disposal should be recorded.

The data in the property record should include:

1. A description of the unit of equipment and information showing its location so that it can be readily identified.
2. The original cost new of the unit and supplementary costs including replacements.
3. Dates of various entries.
4. Repairs and maintenance.
5. Service, age and probable life.
6. Depreciation information including the condition per cent, present value, annual depreciation and the depreciation reserve.
7. Other information that may be essential concerning the operation cost of a particular unit, such as fuel cost, output, and the time used record.

For property record accounting, units of property may be considered as being of three general types: (1) a simple property unit which is one item rendering service as an entity such as a motor, a chlorin-

ator, or a blower, (2) a composite property unit which is composed of one main unit and one or more sub-items which may require separate retirement and renewal during the service life of the main unit such as a clarifier, pump and motor unit, or an air compressor unit, and (3) a continuous unit, which is composed of several separate sub-items whose retirement and renewal from time to time enable the whole unit to remain in service indefinitely, such as a building, water mains, or a sewer line.

Whenever possible age groups of like property items such as meters, hydrants, etc. should be considered as one unit of property to reduce the calculation work and the number of property records.

Property record forms 1, 2, 3, and 4 are illustrative examples designed to show possible arrangements of the form and the information gathered.[1] Plants may differ in the type of form required to meet their needs, and special forms may sometimes be necessary to provide specific information about certain equipment. Standardization of the forms and of the information sought is desirable since it will simplify the records and allow the different plants to compare information more easily.

Forms 1 and 2 are primarily for simple property units but may be used for composite units by providing a sheet for each sub-item. If the probable lives of the different items of a composite property unit are nearly the same, it is often better to consider all the items as one simple unit.

Form 1 provides for a description of the unit, its cost and estimated salvage value, the repair and maintenance costs and the depreciation data. In this illustration the straight line method for computing depreciation was used; however, the sinking fund, present worth or any of the other methods can be used without any modification of the form (see *Manual of Water Works Accounting*, Chapter 11). The rate of depreciation depends upon the probable life of a unit which may for individual units vary considerably from the average life. Inspection of the property at intervals will indicate if the depreciation rate is different from that originally assumed, and if there

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[1] Other examples of property record forms may be found in: Church, *Manufacturing Costs and Accounts*, Second Edition, McGraw-Hill Book Co., Inc., 1929; Marston and Agg, *Engineering Valuation*, First Edition, McGraw-Hill Book Co., Inc., New York, 1936; Paton, *Accountant's Handbook*, Ronald Press Co., New York, 1935; and *Manual of Water Works Accounting*, American Water Works Association, New York, 1938.

PROPERTY RECORD

FORM #1

UNIT – 1000 g.p.m. 2 stage pump with 75 H.P. motor
MANUFACTURER: K-M & T. Co.
M'F'G'R'S TYPE & NO: X-321-C
DEPT: Water
PURCHASED FROM: K-M & T. Co.
PLANT: Westside Pumping Station
INSTALLATION COST: $ 200
COST DELIVERED: $ 1850.00
EST. SALVAGE VALUE: $ 50

REPAIRS			DEPRECIATION					
DATE	DESCRIPTION	COST	DATE	AGE / PROB LIFE	COND. %	PRESENT VALUE	DEPR. RESERVE	ANNUAL DEPR.
11/30/14	Depr. Value	$2000		/20	100	$2050		$100
			12/31/15	1/20	95	1950	$100	100
			12/21/16	2/20	90	1850	200	100
			12/31/17	3/20	85	1750	300	100
			12/31/18	4/20	80	1650	400	100
			12/31/19	5/20	75	1550	500	100
			12/31/20	6/20	70	1450	600	100
Enter date of repairs	Enter description of repairs	Enter cost of repairs	12/31/21	7/20	65	1350	700	100
			12/31/22	8/20	60	1250	800	120
			1/1/23	8/18				
			12/31/23	9/18	54	1130	920	120
			12/31/24	10/18	48	1010	1040	120
			12/31/25	11/18	42	890	1160	120
			12/31/26	12/18	38	770	1280	120
			12/31/27	13/18	32	650	1400	150
			1/1/28	13/17				
			12/31/28	14/17	24	500	1550	150
			12/31/29	15/17	16	350	1700	150
			12/31/30	16/17	8	200	1850	125
	Retired 11/1/31		12/31/31	17/17	0	75	1975	
12/31/31	Salvage Value	$ 75					75	
							$2050	

is a difference between the actual and recorded depreciation, the recorded should be adjusted to agree with the actual depreciation.

In the illustration the pump unit was originally estimated to have a probable life of twenty years, but after eight years of service it became apparent that the probable life would be less than twenty years. Instead of accounting for the deficit in the depreciation allowance all at one time, the deficit was prorated throughout the remaining life of the unit. Similar adjustments may be made to correct for functional depreciation and for absolescence.

(FRONT SIDE OF SHEET)
PROPERTY RECORD
FORM # 2

UNIT:........................ MANUFACTURER:..........................
DEPT:........................ M'F'G'R'S. TYPE & NO:..........................
PLANT:........................ PURCHASED FROM:..........................

RECORD OF REPAIRS			OPERATION DATA			
DATE	DESCRIPTION	COST	DATE	INPUT RECORD	COST	OUTPUT RECORD

(REVERSE SIDE OF SHEET)

DATE	ITEM	COST DELIV.	INSTALL. COST	TOTAL COST	DEPRECIATION				
					AGE / PROB. LIFE	COND. %	PRESENT VALUE	DEPR. RESERVE	ANNUAL DEPR.

Form 2 provides for information on the input and output of a unit such as power equipment, etc. This feature is useful for determining efficiencies and costs per unit of output. The idle time of equipment that is used irregularly may be recorded in a similar way.

Form 3 is an illustrative form designed specifically for composite units, the various items having different probable lives.

Form 4 is designed to facilitate the keeping of cost records for age groups of like property items occurring in numbers which may be grouped and considered as a unit, such as meters, hydrants, etc. This form permits the saving of considerable time and expense since all the items of a particular type installed within a year may be accounted for as a unit. Since only items of the same age are grouped

PROPERTY RECORD FOR COMPOSITE UNITS

FORM #3

UNIT: ____________________ MFG. BY: ______________ REMARKS: ____________________________

DEPT: ____________________ M'F'G'R'S TYPE & NO: __________ ____________________________

PLANT: ____________________ PURCHASED FROM: __________ ____________________________

	REPAIRS		DEPRECIATION												
			ITEM #1			ITEM #2			ITEM #3			TOTAL FOR ENTIRE UNIT			
DATE	DESCRIPTION	COST	AGE / PROB. LIFE	COND. %	PRESENT VALUE	AGE / PROB. LIFE	COND. %	PRESENT VALUE	AGE / PROB. LIFE	COND. %	PRESENT VALUE	PRESENT VALUE	DEPR. RESERVE	ANNUAL DEPR.	DATE

PROPERTY RECORD FOR AGE GROUPS OF LIKE PROPERTY UNITS

FORM #4

UNIT: ____________________ MANUFACTURER: ______________ RATING OR SIZE: ______________

DEPT: ____________________ M'F'G'R'S SERIAL NO: __________ TYPE: ______________

LOCATION: ____________________ PURCHASED FROM: __________

		ADDITIONS				RETIREMENTS		DEPRECIATION					REPAIRS		
DATE	NO. IN SER-VICE	NO.	UNIT COST F.O.B.	UNIT INSTALL. COST	TOTAL INSTALL. COST	NO.	DEDUCT. FROM VALUE	AGE / PROB. LIFE OF OVER-AGE	COND. %	PRESENT OR RESIDUAL VALUE	ANNUAL DEPR.	DEPR. RESERVE	DATE	DESCRIPTION	COST

and accounted for as a unit, the entries in the columns designated "additions" would be for a year and the "number in service" to be accounted for is the total number added during the year.

When any of the items is retired it is listed under retirements. The probable life of the group is the average life for that type of item. Some of the items will be retired before the average life of the group is reached and others will last longer. The rate of depreciation may be changed when it is apparent that the average life of the group will be greater or smaller than originally assumed. If mortality data are available for the specific items, depreciation may be computed on the basis of the probable life of the average surviving item and the retirements. The property record at the retirement of all the units will provide accurate mortality data for future use.

In using property records in a water works, the data on the property records must agree with the general account for the water works in the city's accounting system. The property records will contain detailed data while only the total figures on depreciation, repairs and plant costs, will appear in the general plant account. For example, the property record for a pump unit in a new plant would show the cost delivered and the installation cost, and the plant account would include these costs as part of the summation or lump sum cost of the entire plant. Likewise, any expenditures for repairs on the pump would be entered in detail in the property record but would be entered only as part of the total repair cost for the entire plant in the plant account. The annual depreciation, the depreciation reserve, and the present value of the pump unit should be entered in detail in the property record but would appear in the plant account as part of the total annual depreciation, total depreciation reserve or total value for the entire plant.

While property records on first thought may appear to require a large amount of work, actually after the record system has been established the maintenance of the system need not be laborious.

Handling Complaints About Quality

By G. E. Arnold

COMPLAINTS are one thing with which all water systems whether privately or municipally owned, large or small, old or new have to deal. In spite of the extreme care which is exercised by water works men, conditions arise which may give cause for complaint and there are always some consumers who will complain whether there is reason or not. The purpose of this paper will be to outline, in brief, the procedure used in handling complaints in some water systems and to give the writer's views in this regard.

Complaints may be received from any one of a number of sources or through various channels. With most water systems, they come by telephone, letter, personal visits, or through employees of the water works. Bill collectors get a large proportion of the complaints directly from consumers, particularly those pertaining to high bills. Meter readers bring in comparatively few complaints, particularly where meters are located at the curb.

Complaints may be divided into two general classes: those having to do with the water service, which can be considered of an operating nature, and those concerning the quality of the water. Under operating, the more common complaints are of noise, leaks, poor flow, low pressure, high pressure, closed house valves, high bills, dual systems, and damage claims. Complaints regarding the quality of the water are usually of taste, odor, color, turbidity, temperature, corrosion, sickness, or visible insects.

When a complaint is received at the water department office, it should first be recorded on the proper form. Most water systems are supplied with forms of one kind or another for various inquiries. In the San Francisco department, we have five standard forms for

A paper presented at the California Section meeting at Riverside, California, October 27, 1938, by G. E. Arnold, Chief Water Purification Engineer, San Francisco Water Dept., Millbrae, California.

recording complaints or requests. The forms are all of the same size, 5 by 8 inches, but they are of different colors for different types of complaints. They are usually filled out in triplicate by the person receiving the complaint and are then sent to the department agency assigned to handle this type of inquiry.

Complaints of leaks, closed valves, and noisy meters are handled by service and shut-off men from the Corporation Yard. Most complaints of poor flow, low pressure, high pressure, dirty water, taste and odor are investigated by an inspector from the Water Sales Division. Complaints of high bills or damages are investigated by the Claims and Adjustment Division. Complaints of sickness, corrosion, visible insects, and in some cases, complaints of taste, odor, and turbidity, are investigated by the Water Purification Division.

Filing System Is Important

The filing of complaint forms and reports is an important matter regarding the handling of complaints as it is frequently necessary to trace back to prior complaints from the same address, and it is important to be able to find the information when it is wanted. In the San Francisco system, all consumer accounts are handled by number. The numbers refer to the number of the field book in which the meter readings are recorded and the sheet number in that book. For example, account 46–725 would be in book number 46 on page 725. These books are kept in a vault in the department's head office and are taken out by the meter readers as they go out on their monthly rounds. They are returned to the office at the end of each day.

All bills, complaints, references, letters to consumers, and all other correspondence or notices relative to an account are given this same account number and all filing is done under these numbers. Block maps are kept in the department's vaults on which are kept all the account numbers for every service connection in the system. The account number is not changed when the consumer at any address changes. The name of the consumer is merely changed on the cards and books. Thus, it is possible to keep an accurate check of all business pertaining to any account over a long period. Recently, an account of one of the downtown office buildings was checked regarding a water bill and it was possible within a short time to give the consumer a record of the meter readings, water consumption, and the amount of his bill for a period of 24 years. Accurate filing methods

of this type are indispensable in handling complaints. A system such as this is also of help in keeping down the number of errors made in billing. With 115,000 consumer accounts in the San Francisco water system, in the last two years there have been only two errors in billing consumers.

The largest proportion of complaints received is for high bills. The Claims and Adjustment Division usually makes a satisfactory settlement with the consumer in complaints of this type. During the last fiscal year, there were 785 complaints received pertaining to operating conditions in the Water Department and 591 complaints of the quality of water. The majority of complaints received regarding operating conditions were found to be the responsibility of the consumer. These included such things as house valves closed, house piping too small, valves out of order, building too high, or overloaded service. Complaints for which the department was responsible included choked pipes, service main broken or too small, elevation too high, or district temporarily shut down.

Complaints About Quality Are Few But Difficult

Coming now to the main subject of this paper, complaints regarding quality of water, we find that these complaints constitute on the average a very small percentage of the complaints received, but that they require careful handling and sometimes involve much study and investigation.

The most common source of complaint regarding the quality of water is unclean or discolored water. This is apt to occur in systems not equipped with filter plants and where an impounded surface supply is used. In some systems supplied from wells trouble is encountered with fine sand being pumped into the distribution pipes. Deposits of sediment will form in the mains in time and these deposits will be disturbed from various causes resulting in the consumers getting dirty water. This is particularly true in systems where the distribution piping is of large size for fire protection purposes. Were the street mains of sufficient size only to care for the normal domestic consumption, sufficient velocities would maintain to prevent the deposit of sediment. Most water systems, however, are built to take care of future growth and to provide adequate capacity for fires and other emergencies. Fires or street washing operations are a frequent cause of dirty water in mains. Reversal of flow or temporary shut-down of districts for repair work will frequently result in dirty water.

If a water supply is at all corrosive, it will at times tend to result in discoloration of the water. The usual treatment for such complaints is to treat those portions of the system affected until the water clears up. Sometimes flushing operations will not be possible and the consumer has to wait until the deposit settles in the mains. Treatment of the supply to render the water non-corrosive will keep down corrosion complaints. Judicious flushing of street mains as a regular procedure, particularly near dead ends, is frequently advantageous in preventing the accumulation of sediment in mains.

The next most frequent source of complaint is taste or odor. Taste or odor may come from a number of things in the water, the principal ones being algae or other organic growths, stagnation, especially near dead ends, and weed growths in open reservoirs. Occasionally, chemical treatment of the water supply results in taste or odor production. When a taste or odor enters a distribution system, an investigation should immediately be made of the source. If the difficulty can be corrected, flushing of the system to remove the affected water is probably the best method of eliminating the trouble. Where taste or odor develops near dead ends, flushing of the dead end to remove the stagnant water is probably the best remedy. The complaint of taste or odor can frequently be traced to an origin on the consumer's premises.

Old Piping Is Source of Much Trouble

One common source of taste or odor in the consumer's premises is the use of old piping when changes or alterations are made in the plumbing system. Occasionally a plumber or house owner will use a piece of pipe or a fitting in a water line which has formerly been used in a gas line. Any piece of pipe which has ever been used in a gas line will impart an objectionable taste and odor to the water and will probably never clear up.

Foul kitchen sinks sometimes cause apparent odors; also cooking vessels used for certain foods. In one case, a complaint of odor was found to come from a vent on a sewer line which opened near a kitchen window. Another common cause of taste or odor is the non-use of water within a building. New tenants moving into a place that has been vacant for some time will frequently complain of the taste or odor in the water and the cause can frequently be traced to the lack of circulation in the piping. This may take days or even weeks to clear up. New buildings frequently have trouble with taste and odor in the water from new piping and from the compounds used in

the pipe joints. Sometimes piping with an asphalt lining is used in the building which imparts a taste to the water. New construction on the part of the water works may result in taste or odor in water and new piping should be thoroughly flushed before being placed in service.

A few complaints are received of warm water. These temperature complaints can usually be traced to the proximity of the water piping to heating or steam lines within the building, although a slight rise in temperature has been recorded where a distribution main is laid close to the surface where a street is paved with asphalt. The number of complaints of this type is usually small.

If a public water supply is corrosive, complaints are received from time to time of corrosion of the piping, particularly hot water systems. Corrosion of the piping results in rusty or red water, and complaints are frequently received from laundries or industrial plants where rusty water is a serious matter. Treatment of the water within a consumer's premises with lime, sodium silicate, or some other chemical frequently overcomes this difficulty. In many cities, treatment of the entire supply is practiced.

The public is prone to blame any sickness which may occur in the family on the public water supply. Complaints of sickness should always be carefully investigated and samples of the water from the consumer's premises should be examined in the laboratory. It is the policy of the San Francisco department to investigate immediately any complaint regarding sickness. To obtain a sample of the water from the consumer's premises and to notify the consumer of the result of the test not only puts the consumer at ease, as the water is invariably found to be of satisfactory sanitary quality, but it is also a protection for the water department against damage claims or law suits.

Ammonia Turned the Meat Red

Some complaints are of a nature that requires considerable investigation and study to determine the source. One such case involved an exclusive club where the chef complained of the meat having a bright red color after being boiled in city water. He was certain it was the water which caused the trouble because upon boiling meat in bottled water, this red color did not appear. After considerable investigation and study, it was found that the difficulty came from a leak in the refrigeration system which permitted a small

amount of ammonia to escape from the refrigerating plant into the water line leading to the kitchen. Apparently, the ammonia reacted in some way with the meat during the boiling to give the meat a bright red color. Investigations of this type while troublesome are advisable as the consumer feels that the water department has performed a service and the consumer usually becomes a booster.

The personnel used for complaint investigations should be carefully selected and properly trained. Contact between the department and the consumer at the time a complaint is received is of paramount importance. The consumer is apt to be wrought up and unless diplomatically handled may form an impression which can do the department considerable harm. Courtesy and interest in the consumer's troubles are of first importance. A complaint investigator should have a knowledge of the water system in which he is working and of the treatment methods used. He should be somewhat familiar with the chemistry and biology of water treatment and should be able to give a clear explanation of this knowledge to the consumer.

Where an individual is assigned to the investigation of complaints, he should not attempt to explain factors regarding the water supply which he does not fully understand. The majority of complaints can be taken care of by a person without technical training but in some instances a thorough knowledge of the science of water supply is necessary and if the regular complaint investigator does not have the proper training, complaints requiring scientific explanation of water treatment should be handled by someone who does have this training. Nothing creates a better impression with the consumer than a call from a man who knows his business and can give a satisfactory explanation of the difficulties being encountered.

Field Tests Convince Consumers

A few simple tests made on the consumer's premises will be of value in convincing the consumer that something is being done to rectify his trouble. In the San Francisco system, inspectors are equipped with small test kits containing a number of reagents and bottles for making simple tests in the field or the consumer's building. Such tests as dissolved oxygen, pH, and alkalinity can readily be made in the field and the consumer is usually impressed by the technique of the determination. Some tests of this type have to be made when the sample is obtained as the water condition will change before the sample can be returned to the laboratory.

The department can do much to build the good will of the consumer by observing a few simple rules or regulations. In most communities, the housewife customarily does her weekly washing on Monday. It should, therefore, be a rule, where possible, that repair work, temporary shut down of a portion of the system, and flushing activities, not be done on Monday. In many cases, it is advisable to do flushing work or any repair work which may disturb the system at night.

When an investigator calls at a consumer's premises in response to a complaint, it is well to make as thorough an investigation as possible of the premises for sources of complaint within the consumer's piping. It is also advisable to obtain a sample of water and send it to the laboratory for analysis. In some cases, the only laboratory test necessary is to determine the presence or intensity of taste or odor. In some cases, a bacteriological or chemical analysis is advisable. A consumer always feels that something is being done in his behalf when a complaint investigator obtains a sample of the water and takes it away with him. It is advisable to notify the consumer of the results of the test and, if possible, to make some comment regarding what steps are being taken to rectify the trouble.

One water system in the East has discontinued the use of the word *complaint* and substituted therefor the word *inquiry*. Experience in this instance has shown that the majority of people are desirous of making inquiries or constructive criticism rather than complaints and the word inquiry makes a better impression with them than to classify their inquiry as a complaint. In any event, courteous treatment of a consumer and a careful, interested investigation of his difficulty is a vital function of the water supply business.

Discussion by *J. D. De Costa*.* Mr. Arnold has presented the facts relative to handling complaints in a comprehensive manner, and has also described the system in effect in San Francisco. There is little that I may discuss in connection with Mr. Arnold's paper, but a description of the East Bay Municipal Utility District's procedure in handling consumer's complaints may be of interest since it varies to some extent from the system used in San Francisco.

In the East Bay, practically all complaints and inspection work are handled by a department known as the Inspection Department,

* Distribution Engineer, East Bay Municipal Utility Dist., Oakland, California.

which works under the Distribution Engineer and consists of a Chief Inspector, two inspectors and two blowoff men. In addition to handling consumer inquiries and complaints, the Inspection Department makes hydrant flow tests, checks zone line changes and makes field investigations as required for the various departments.

Complaints of the so-called operating nature are classified as noise, leaks, poor flow, low pressure, high pressure, closed house valves, excess bills, cross-connections, advice to consumers and other information for the district. Complaints regarding the quality of the water are classified as hard water, taste and odor, turbid water, rusty water and unconfirmed by investigation. In the East Bay we have one standard form for recording all complaints, due to the fact that experience has shown that the information received from the consumer is often in error as to the nature of the trouble.

Flushing Removes Causes of Complaints

Complaints of turbid water usually result from excessive draft on the mains, reversal of flow and shutdowns for new connections or repairs. The East Bay has had a modern purification system for many years and the water entering the distribution system is perfectly clear. But prior to filtration, the system carried unfiltered water and as a result, many of the old mains have large deposits of mud which, upon disturbance, give rise to turbid water. Turbid water complaints in the East Bay are always confined to small sections of the system and the condition is easily remedied by flushing the affected areas through hydrants and blowoffs. Another source of annoyance to both consumer and water works men is "milky water" which is caused by an excess of dissolved air. Air enters the mains during shutdowns or through leaky packing glands on pumps operating under a negative head. After the source of air is determined and corrected, the milky water is removed from the mains by flushing through hydrants and blowoffs.

Since we have been adjusting the pH of the treated water by the application of lime, the few rusty water complaints registered originate from hot water systems. These are usually traced to old wornout pipes or to heating the water to excessive temperatures due to inadequate heating facilities.

Very few complaints of hard water are received and none are justified because the principal source of supply for the East Bay has a total hardness of less than 20 parts per million and the maximum

hardness reaching any consumer is less than 80 p.p.m. However, it is not unusual to receive complaints that the water is so hard that it will not form suds in the dish or laundry water.

Taste and odor complaints are the most troublesome and difficult to evaluate. During the past ten years, there has been one or two instances in which the water from one of the sources of supply had a slight algae flavor—resulting in widespread complaint. On such occasions it is impossible to call on all persons who complain, but the cause of the trouble is explained to them over the phone and they are assured that, despite the unpleasant taste, the water is perfectly safe for all uses and that measures are in progress to correct the bad condition. The layman is prone to associate foreign tastes and odors with typhoid fever and other infectious diseases. Assurance from the Water Department that the water is bacterially safe will usually ease troubled minds, even parents who have small children.

Consumer's Piping Causes Many Complaints

Taste and odor complaints arise from various causes other than the source of supply over which the District has no control. Newcomers to the East Bay will invariably complain of the flavor of the water. Each water has its peculiar taste or lack of taste as the case may be. People accustomed to hard waters dislike the flavor of soft waters and vice versa. Bad water conditions often originate within the consumer's equipment, due chiefly to allowing the hot water system to overheat and back hot water into the cold water pipes. Foul kitchen sinks and odoriferous foods in the kitchen often give rise to complaints of taste and odor in the water. Numerous cases are on record of the installation of used gas pipe in the house water lines. New plumbing and premises that have been vacant for long periods invariably cause complaint of taste and odor. Taste and odor complaints for which the District is responsible are caused by dead ends, sparsely settled areas where circulation is poor, and also by the installation of new pipe lines.

All consumer complaints for which the cause is not definitely known are immediately investigated, proper corrective measures taken and the consumer advised of the findings and results obtained. In case of sickness in the family, a sample of water is taken from the consumer's tap for a bacterial examination and the results of the examination reported to the consumer.

The two blowoff men devote nearly all of their time to flushing

dead ends. One has a list of so-called chronic cases that require regular attention, some dead ends being flushed as often as twice each week, others every month or two. The second blowoff man covers all dead ends, not classified as chronic. In the routine flushing, each dead end is flushed about twice each year. In addition to this, the entire system is systematically flushed every few years. This work is done during the night in order to cause the consumer the least possible inconvenience.

The men selected to handle consumer complaints must, of course, have a good appearance, be good conversationalists, have a working knowledge of purification and distribution, and be capable of dealing with the public. They are taught to be good listeners, courteous under all circumstances, accurate in their statements and to consider all complaints serious, no matter how trivial they appear to be.

Complaints Concerning Water Service

By Fred S. Porter

IN A discussion of consumer complaints relating to service of water which have been made to the Long Beach Water Department, it might be of interest to mention a few facts regarding the system and state in a few words the method in which the department records the complaints received.

Long Beach, with an estimated population of 170,000, receives its share of every kind of complaint imaginable. There is a great deal of territory from which to gather complaints, considering that the distribution system of the department consists of 413 miles of cast-iron mains ranging in sizes from 2 to 30 inches, and 25 miles of steel mains ranging in sizes from 2 to 24 in., making a total of 438 miles; 13,941 cast-iron service laterals ranging in sizes from 2 to 10 in., of which 41 are larger than 2 in.; 23,567 galvanized iron service laterals ranging in sizes from $\frac{3}{4}$ to 6 in., 92 per cent of which are $\frac{3}{4}$ in.; 7,177 gate valves; and 3,186 fire hydrants. On September 30, 1938, the department had 31,206 meters in service.

Complaints are recorded at our Service Plant, from which the service and construction crews are dispatched. At the office of this plant three shifts of dispatchers are maintained during the whole 24 hours of the day to receive complaints and send out crews to make investigations as well as to make repairs or to correct dangerous conditions reported to them.

Complaints are also received during office hours in the collection division at the main office. All complaints concerning meter leaks, noisy meters, non-registering meters and high bills are investigated by troublemen dispatched from this office. Complaints that can not be handled by the troublemen are relayed to the Service Plant for disposition by the dispatchers.

A paper presented at the California Section meeting at Riverside, California, October 27, 1938, by Fred S. Porter, General Manager, Long Beach Water Department, Long Beach, California.

The complaints received at the Service Plant are recorded in bound "Standard Figuring Books." Complaints received and investigated by troublemen from the staff of the collections office are recorded in duplicate on forms numbered consecutively which are provided for that purpose. The duplicates in the bound books are kept in the office. The originals are removed from the book and given to the investigator who makes his report in the place provided on the form. When the investigation is complete, the slips are filed numerically for future reference. Before this is done, however, if the complaint is one regarding a meter, a notation giving the number of the report is made on the meter sheet in the meter book to be used for ready reference in case of a controversy.

The above described method affords a permanent record, is useful in discussing complaints with consumers and has provided very effective evidence in law suits.

High Water Bills Are Most Common Cause

High water bills probably occasion the most common complaints made by the consumer. Our department minimizes complaints from this source by checking the meter readings and, whenever possible, making investigation for causes of high bills before the water bills are sent out. If our investigation reveals the cause of a rise in the bill, often we are able to notify the consumer of the trouble before the bill is sent out. Some of the reasons given by the consumer as to why they are not responsible for the high bill are: that the premises were vacant during the period covered by the bill; that no water was used for bathing during the summer because they took their baths in the ocean; that two or more of the family bathed in the same tub of water.

A common cause of high water bills is the leaky toilet valve. Most consumers will deny that they had a leaky toilet even when the investigation indicates this was the cause. In one case the investigator's inspection showed that the rubber bulb had been replaced, and still the consumer insisted that no work had been done on the fixture! As the investigator was leaving the premises he looked in some weeds near the back door which presented a possible hiding place where the old bulb might have been thrown. He found it, and when the evidence was presented to the consumer the bill was paid without further argument.

The department received a written complaint from a canning

company regarding the high water rate in the city and a request for a special rate to them because they were to increase the size of their plant, which would result in the employment of more people.

A report was compiled and sent to this company showing the amount of water used over a period of two years and comparing the cost of Long Beach water with the cost of the same amount in other cities where they might locate. Although their request for a lower rate was not granted, the manager of the company was sport enough to send a letter thanking the department for the information it had furnished and stating that he was perfectly satisfied to remain in Long Beach.

Leaks Are Commonly Reported

Every water department has a great number of calls reporting leaks in the streets which, upon investigation, prove not to be water leaks. It is also probable that the public assumes that leaks have occurred in the distribution system whenever water has accumulated in the streets. Our experience is that when the water is not from a leak in a main or service, it may be from an ice wagon, excessive lawn sprinkling, washing of cars and, in many instances, from a broken or clogged sewer main or house connections.

In certain low sections near the ocean we sometimes receive calls from a great many people that a water main has broken and flooded an entire area. These calls come during the season of the year when excessive high tides occur. It may be true that the area is flooded, but it is usually not from water escaping from a broken water main. Often it is salt water which has backed up through the storm drains and caused the flooded condition.

We received a complaint which stated that water, leaking from several holes in a steel water main, had been forced laterally from the alley and under the consumer's property, thereby causing the salt in the ground to come to the surface, thus killing the lawn and shrubs. The party threatened to bring suit to recover for loss of shrubs, lawn and flowers. An investigation left no doubt as to the fact that they had been damaged by salt coming from the ground. An inspection of the vacant property across the street revealed that a crust of salt had accumulated on the surface of the ground. After the condition of the vacant property was drawn to their attention, and their faulty theory regarding the movement of water from leaks in a main was pointed out to them, they realized that the salt was

probably brought to the surface by sprinkling and rains and they were apparently convinced that they could not recover any damages from the Water Department.

Many complaints are received because of the temperature of the water which during the summer ranges from 82 to 85 degrees as it enters the distribution system at the reservoirs, and 80 to 82 degrees in the system in the business section of the city. Some of our deep wells produce water which has a temperature of 96 degrees.

Photograph finishers have complained that at times the water is too warm for their use. Upon being advised that the summer temperature of the Long Beach water ranged from 80 to 82 degrees, a representative of an air-conditioning firm remarked that our water was no good as a cooling medium, but could be used better for heating purposes. Even our own girls in the department complain that they can not keep flowers in the office fresh because the water is too warm!

Water Hammer Complaint Justified

During the recent oil development a number of complaints from the northern section of the city were received over a period of two or three days reporting heavy water hammer shocks in the water pipes. The shocks were so heavy that the complaining consumers feared that damage would be done to their plumbing. The trouble crew, making an investigation, could find no evidence of water hammer in the mains, nor did the recording pressure gage in that vicinity show any evidence of excessive pressure which would be caused by water hammer shocks. Meanwhile reports continued to come in that shocks were occurring at intervals of about every twenty minutes. Finally, one of the foremen discovered that a geophysical exploration crew employed by one of the oil companies was exploding charges of dynamite about twenty feet below the surface of the ground about one-half mile from the source of the complaints.

Shortly after one of our wells, which pumps directly into the distribution system, was placed in service, we received a complaint from a consumer living a few blocks away from the well, that the Water Department was doing something that threatened to tear her plumbing loose and wreck her house. Our pressure chart records showed that the lady's complaint was justified. They indicated that a heavy water hammer shock occurred once or twice a day

which threatened damage to the consumer's plumbing as well as the department's mains.

A further investigation showed that shocks occurred when the pump at the well was started. It was finally discovered that the absorption of the air by a gas in the pressure tank, which should have served as a cushion to absorb the shock caused by the starting of the pump, was the real cause of the terrific and sudden water hammer. This condition was corrected by periodic introduction of air in the tank, thereby insuring its normal operation. It might be interesting to mention at this point that it takes about eighteen hours for the gas to absorb the air in the pressure tank.

Water Hammer Wrecked Recorder

Some years ago, we received a complaint from the engineer in charge of the Southern California Edison Company's big steam plant in the Long Beach Harbor District to the effect that on several occasions a pressure recorder in their plant, connected to the line supplying them with city water, showed a tremendous water hammer; a shock so heavy that on one occasion, at least, the helical spring of the recorder was permanently deformed. He submitted some charts taken from the wrecked instrument in proof of his statement.

The charts showed a series of shocks, varying in intensity, and occurring at all hours. The heaviest ones were beyond the capacity of the instrument to register, and following one of these, the pen traced a record some 20 or 30 pounds too great. We were requested to ascertain what was going on and to put a stop to it before additional recorders were wrecked. We were assured that there was no cross-connection within their own plant and no chance that the shocks originated on their own property.

An investigation of the various plants in the industrial district was carried on over a period of several weeks. These investigations revealed the cause of several of the minor shocks. However, we still had no clue to the cause of the heavy shocks which continued to occur, generally about 4:00 o'clock in the morning.

After some questions concerning the Edison Company's operating personnel, we were able to point out the fact that the majority of heavy shocks occurred shortly after a certain night engineer came on duty, and we suggested that some one be detailed to observe him without appearing to do so.

Several weeks went by before one of the Edison Company's

engineers telephoned us and told us that they had discovered a cross-connection in their own plant. He stated that their operating schedule called for the filling of an overhead tank from their own well each afternoon. This tank full of water was expected to carry their boilers throughout the night, and until the day shift came on again. But the night man claimed that the tank frequently ran dry shortly after he came on shift. He then simply opened a gate that nobody else seemed to have any knowledge of and pumped direct from our line. Their plunger pump did the rest.

It cost us considerable to dispose of the original complaint, but we felt that the conditions disclosed and corrected as the result of our investigation more than offset the expense.

The department has received many complaints from consumers that their water has been turned off. If a check shows that no work is being done in the vicinity which would cause the water to be turned off, or if the water has not been turned off because of non-payment of a bill, the consumer is advised to ascertain whether or not the valve generally installed at the house for use during repairs of house plumbing has inadvertently been closed. In a great many cases this is the cause and is easily corrected.

The department, upon investigating one of these complaints, inspected the valve at the house and found it open. The crew then removed the meter in search for the trouble and found it was in proper working condition. The 2-inch service was then cut at the main beyond the corporation cock and the service lateral was also checked and found in proper order. The main was then closed down and the $1\frac{1}{2}$-inch corporation cock was removed. This revealed the cause of the lack of water in the service. A golf ball was found lodged in the inner end of the corporation cock. The ball had probably been thrown into a main in the system during construction and had traveled to this service. Other marks on the ball show that it had been lodged in a corporation cock at least twice before, but on each of these occasions had fallen back into the main again.

Developments in Water Treatment

A Review

By Willem Rudolfs

SOME of the more interesting results and suggestions from recent experimentation in water treatment have been gathered together for presentation, especially those dealing with algae control, iron and manganese removal, treatment for color, taste and odor, corrosion, softening, and something on coagulants and filter troubles.

Considering, first, algae control, it appears that algae activities may vary with the ultra-violet ray radiation from the sun; periods of greatest microscopic growths in reservoirs occur when ultra-violet radiation is greatest and water temperature and hours of sunshine low. Los Angeles uses ultra-violet ray measuring devices, and when activity of such rays is on the increase, the reservoir dosing with copper sulfate or chlorine is increased; while when ray activity is on the decrease, even though microscopic counts are somewhat high, treatment is postponed. Applying this method, there has been a saving of 20 per cent of chemicals used in treating reservoirs, but the water has had greater freedom from tastes and odors.

Attempts to control algae by continuously adding copper sulfate solution to the water as it left the reservoir for the filter plant, in Albany 8 miles away, killed the algae, but diatom cells remained intact and clogged the filters as much as when alive. The next method tried was to treat a part of the reservoir adjacent to the gate house with copper sulfate from a speed boat. Blue-green algae developing on concrete side slopes of four distributing reservoirs form a mat there, and are controlled by shoveling onto the mats dry small crystals of copper sulfate which become mixed with the deposit, slowly dissolve and discourage further growth.

A Journal Series paper, New Jersey Agricultural Experiment Station, New Brunswick, N. J., by Willem Rudolfs, Chief, Dept. Water and Sewage Research. This paper was presented at the New Jersey Section meeting at Asbury Park, N. J., October 22, 1938.

Algae growths in Lake Winnebago, Wisconsin, caused serious taste and odor troubles in the water supplies. Experimenting with carbon, ozone, aeration, etc., led to the conclusion that "activated carbon was the most practicable and positive method of removing tastes and odors" from this water used either as powder or granular in beds. Comparison showed that 120 lb. of granular carbon operated to exhaustion had the capacity of 176 lb. of powder; but the latter was cheaper; and the installation cost was nominal, while granular filters are more costly to build and maintain. The plants have not been operated long enough to determine the life of granulated carbon, but the experimental studies conclusively demonstrated that "the life would be very short unless the real work was largely done by powdered carbon."

Algae removal from lake water at Portland, Maine, by means of a Laughlin magnetite filter was tried. "The results up to date have been very favorable. Three-quarters of the vegetable matter has been taken out of the water at a high rate of flow."

Algae growth in river water at St. Joseph, Missouri, was controlled by chlorine under some conditions. At Council Bluffs, Iowa, algae in open reservoirs was controlled by maintaining chloramine residuals of 0.5 p.p.m. or greater, supplemented with applications of copper sulfate, such residuals also giving improved bacterial conditions in both reservoirs and distribution system. At St. Joseph, ammonia is satisfactory as a preventive for many tastes and odors and as an inhibitor of after-growths, while activated carbon is efficient and economical in controlling tastes and odors of short duration. At Council Bluffs, chloramine together with activated carbon does away with much reservoir washing and dead-end flushing; chloramine residuals as high as 1.0 p.p.m. produce no chlorine tastes if enough of the organic matter has been removed by activated carbon before the ammoniachlorine is applied.

Color, Taste and Odor Considered

Color removal depends chiefly on the production of a stable adsorptive floc which will settle rapidly, will not break up, will not redissolve or pass the filters. With careful plant control such a floc can be secured. In a majority of soft, colored waters it is necessary to correct the final reaction of the water to prevent corrosion in the distribution system. Both lime and soda ash can be employed. While it has been customary to leave the pH figure at 7.5–8.0,

modern tendencies are to maintain the final figure at approximately 9.5. Standard practice is to secure a color of not greater than 20, and 15 is more desirable.

Color removal at Ottawa, Ontario, is effected by coagulation, settling, rapid sand filtration, lime corrective treatment and sterilization. The raw water has a pH of 6.9 to 7.4 and a color of 40 to 80 p.p.m.; alum coagulant reduced the color to 3 p.p.m. Filter effluent pH is 5.5 to 6.1, corrected by sufficient lime to convert all free carbon dioxide to calcium bicarbonate with a small excess, giving an effluent pH of 8.4 to 9.1.

Pre-chlorination at Salem-Beverly, Massachusetts, for controlling tastes and odors resulted in larger (alum) floc formation, permitting the cutting of the alum dosage by several per cent. For odors due to microscopic organisms, best practice seems to be to destroy the organisms by pre-chlorination and then remove the odor by carbon, using 5.5 lb. per m.g. of chlorine and 20 lb. of activated carbon. (See Jour. A. W. W. A., **30:** 369, February, 1938).

Tastes and odors at Culver City, California, due to iron and sulfur bacteria in the ground water supply were removed by means of three pressure filters containing 42 in. of granular activated carbon on 3 in. of filter sand, resting on several layers of graded gravel surrounding a standard strainer system. The filter rate is $3\frac{1}{2}$ gal. per min. per sq.ft. of surface; backwashing rate, 12 g.p.m. per sq.ft. Water is pre-chlorinated with 0.5 p.p.m. of residual chlorine at the filter inlet. Effluent was clear and devoid of taste. After two years of hard service the carbon was found to have lost about 50 per cent of its effectiveness; cost of carbon was calculated to be $3.10 per m.g.

Chlorine Taste Added to Water

Adding taste to a water supply instead of removing it is to be practiced by Birmingham, Alabama, in supplying water for industrial purposes only. It is proposed to super-chlorinate the water to give a taste to serve as a warning that it was not a potable supply, at the same time sterilizing it to protect any chance drinker against disease germs. Incidentally the chlorine probably will help to prevent the collection of slime in condenser tubes of power plants using the supply.

Of the two methods available for measuring the odor-removing capacity of activated carbon, the phenol test is of secondary importance to the threshold odor test. In many cases the odors are not

caused by phenolic compounds and respond to carbon absorption in a manner markedly different from that of phenol. On the other hand, the threshold odor test provides a method of evaluating carbons directly on the water to be treated and can be relied upon for accurate results. There is need, however, for a satisfactory test which can be used as a convenient basis for the purchase and manufacture of carbons.

The American Water Works Association has published tentative specifications embodying both the phenol and threshold odor tests (Jour. A. W. W. A., **30:** 1159, July, 1938). Changes are probable because the use of activated carbon is still being developed. Many odors are so strong that producing odorless water with present procedures is impracticable though possible. Only a small fraction of the odor-reducing capacity is now being utilized; there should be better methods of getting carbon in contact with the water. Both carbon manufacture and the method of using carbon should be improved.

Iron and Manganese Removed by New Methods

Iron removal from well water containing more than 10 p.p.m. iron to produce practically iron free water has been accomplished through full cone spray nozzles arranged in rows set at an angle of 45° so that the two rows of spray are directed toward each other and fall into basins, after which the water flows to coke layers 4 ft. deep.

Iron removal without aeration is in service at the Queens, New York, pumping station where, in 1935, well water had its iron content reduced from an average of 3.40 to 0.22 p.p.m., and at the same time the free carbon dioxide was reduced from 35.7 to 0.0 (Jour. A. W. W. A., **28:** 1577, October, 1936). The filtered water contains no dissolved oxygen and no free carbon dioxide and enters the mains practically non-corrosive. The plant adds sufficient hydrated lime (low in magnesia) to neutralize the free carbonic acid to form calcium bicarbonate and produce a pH slightly over 8. Provision was made to introduce air to produce an oxygen content of 1 p.p.m., but has not been used.

Iron and manganese removal in Lincoln, Nebraska, where water contains 0.25 to 1.25 p.p.m. of manganese and 0.3 to 0.6 p.p.m. of iron, is effected by: (1) pre-chlorination at wells (keeps low service lines free from *Crenothrix*); (2) aeration—water drops through three tiers of four coke trays, 16 in. apart vertically; (3) chlorination of

water leaving aerator about 1 p.p.m.; (4) contact filters with upward flow of 8 g.p.m. per sq.ft. and a filter medium of $\frac{1}{4}$-inch uniform gravel; (5) sedimentation, 2-hour detention; (6) rapid filters—4 g.p.m. per sq.ft., 2 ft. of graded sand on 18 in. of graded gravel. At present 35 per cent of the raw water manganese is removed in the contact filters, 15 per cent in the settling basin and 45 per cent in final sand filters. Iron is reduced to 0.02 p.p.m.

Manganese in water at Larchmont, New York, coated the sand grains of the filter, forming "a contact catalytic mass in the sand beds," which reduced the manganese in the water from 0.8–1.0 p.p.m. to 0.15–0.20 p.p.m. It was therefore decided not to replace the sand or try to remove the manganese coating. In a laboratory test of the sand it was reactivated with a strong solution of sodium hypochlorite and reduced from 10 p.p.m. of manganese in the water filters to less than .05 p.p.m. The manganese coating does not substantially increase the specific gravity of the sand or hamper the filter washing. Similar results have been obtained in the Northwest.

It appears that removal of iron from water containing free carbon dioxide is at some places best effected by the contact-type filters. Success depends mainly on selection of the degree of preliminary aeration, determined by the comparative carbonate hardness. Operation is limited to filter washing, down-washing once a week and pressure up-wash once a month. The higher the iron content of the raw water, the more complete the iron removal. Iron contents up to 15 to 20 p.p.m. are reduced continuously to 0.05 p.p.m. and even to 0.02 p.p.m. It is recommended that the plant construction be such that no iron is in contact with the water between preliminary and final aeration. The final aeration should be as complete as possible, especially with a water running low in carbonate alkalinity.

Corrosion Theories Have Dissenters

The question of effectiveness of chemical treatment for the control of corrosion is again coming to the fore, especially in connection with deep ground waters. The current theory is that carbon dioxide is not very important in this connection. However, a number of dissenters feel that carbon dioxide may be very important when deep well waters are handled, which may be free from oxygen, but contain carbon dioxide. In bringing together a number of studies made by us during the last several years, where the chemical constituents of the surface as well as ground waters were correlated with the cor-

rosiveness of the waters, it is evident that carbon dioxide may play an important rôle.

Corrosion studies conducted at Columbus, Ohio, indicate that low alkalinity water in which all or nearly all the calcium and magnesium are in the form of normal carbonates, at a temperature of 150°F., is more corrosive to galvanized metal than water containing no normal cabonates, even though dissolved oxygen is appreciable and some free carbon dioxide is present; and that corrosion of zinc depends more upon the alkalinity or pH of the water than upon the dissolved oxygen present.

Carbon Dioxide Neutralized with Lime

Neutralizing carbon dioxide with lime rather than soda ash has been adopted because of the low reactive power of soda ash. Lime is applied to the filter influent with the idea of increasing the filter runs by coating the sand grains with lime to increase their size.

Magno-double salt is a new medium for neutralization of corrosive action made by roasting dolomite, driving the carbon dioxide off from the magnesium but leaving it in combination with the calcium. In reacting with water containing carbon dioxide, one atom of magnesium in the double salt combines with two molecules of carbon dioxide, whereas one atom of calcium combines with only one molecule of carbon dioxide. It may be used in an ordinary rapid filter, being replenished as it is consumed. Hot water can be circulated through it and proper equilibrium established. It can be used for deferrization and demanganization in combination with neutralization. The material is made in Germany (Jour. A. W. W. A., **30**: 2105, December, 1938) and it has been announced that the material would be made here.

Studies made seem to indicate that corrosion products can be removed from metallic pipes, inexpensively and without damage to the metal surface by the use of inhibitors in acid solutions, these inhibitors being certain organic materials such as aniline, pyridine, quinoline, certain coal tar products, bran, flour, glue, etc. "The inhibitor, its concentration, working temperature, etc., should be studied carefully in the laboratory before being used in the piping system. Although the method has not been applied to the larger pipes in the distribution system, it seems that such application may be practical and offers an excellent field for research." The experiments cited were all on house plumbing.

Zeolite softening is conservatively guaranteed to remove 2,800 grains of hardness per cu.ft. of mineral when regenerated with 0.4 lb. of salt per 1,000 gr. of hardness removed, but usually runs from 3,000 to 4,000 gr. Increase in hardness tends to reduce exchange capacity. The entire sand layer must be kept loose and free so that there is no channeling, if good exchange values are to be maintained. A completely drained unit should never be filled from the bottom at a rate greater than 2 gal. per min. per sq.ft. With some waters carrying manganese, *Crenothrix* forms a yellow liver-like coating on the sand but is prevented by applying chlorine to the raw water. Immediate change from hard to soft water may cause intestinal disorders in consumers. It is better to change gradually.

Coagulation of water when using alum may decrease in efficiency as the temperature falls, frequently becoming almost a complete failure; while iron salts seem to be ideally suited for cold water coagulation. "Offering much promise is the use of a small quantity of bleaching powder to aid in the oxidation of copperas . . . . If as little as 5 per cent of the necessary chlorine be obtained from the hypochlorite, the improvement is apparent. It is evident that it is quite possible, but now commerically impracticable, to produce the entire reaction of chlorinating the copperas with this calcium compound."

Coagulants should be mixed with water more slowly and for a longer time in winter than in summer, requiring two to three times as large a mixing chamber, obtained in the case of baffle chambers by installing take-off gates at quarter points or by other fractional division. If mechanical mixing is employed, there should be a number of units, one or more of which can be cut out in winter. "Flexibility in this important step of coagulation is usually neglected and there is great need in most plants for careful consideration in design."

Silica aids coagulation with alum (presumably by a colloidal hydrous silicon dioxide possessing a strong negative charge), and adding more silica materially shortens the time required to coagulate with aluminum or ferrous sulfate and causes the production of larger and tougher flocs, permitting higher filtration rates. The amount of silica (as SiO_2) required to give nearly maximum aid to coagulation with alum is approximately 40 per cent of the amount of alum used. Water containing considerable magnesium may be coagulated by use of lime and silica alone. Acid-treated sodium silicate aids co-

agulation with other aluminum salts, such as aluminum chloride and aluminum nitrate. Considerable aid is given by silica to coagulation of water with ferrous sulfate, but less to ferric salts. However, the presence of silica, even as little as 5 p.p.m., in feedwater for high-pressure boilers is a most disturbing problem and the cause of costly maintenance and operation charges. Also, it causes deposits on steam turbine blading and may have a destructive effect on steel.

Cleaning filters with sulfur dioxide has been demonstrated successfully at Baltimore, Maryland, and at Batavia and Valley Stream, New York, after having been developed at the plant of the West Virginia Pulp and Paper Co. The gas is introduced into the filter outlet and enough wash water supplied to give a 2 per cent solution and fill the filter. The unit was allowed to stand several hours, drained off, and backwashed. Frequent weak solutions are preferable to one strong one. Advantages claimed are: that sulfur dioxide is easily obtained at reasonable cost; that application is simple; labor required is only that of one man for a few hours; that the sulfur dioxide removes manganese and iron, kills bacteria and plankton, disintegrates mud balls, opens closed ports in collector pipes, and is less dangerous to handle than sulfuric acid, sodium hydroxide and many other aggressive chemicals; and that removal of sand is unnecessary.

Chlorine demand determinations by the standard methods are "quite unsuitable for finding the dosage of chlorine in ammoniated water. In water purifying plants using ammoniation the dosage of chlorine is chosen empirically and then verified by bacteriological count."—which is undesirably slow for operation under variable conditions. (See Jour. A. W. W. A., **29**: 1761, November, 1937). The now-existing iodometric method does not take into consideration the influence of the initial dosage of chlorine on the chlorine demand and the influence of ammonia on the same; or of acidification during back titration of the residual chlorine. Koshkin describes a proposed method for determining the dose of chlorine for ammoniated water which "takes into consideration the value of initial chlorine, the value of half-bound chlorine, and the diminished chlorine demand of water upon influence of ammonia. When so determined, the chlorine dose always produced a fair bactericidal effect. When the dose of chlorine is determined according to this method the residual persists for a sufficiently long period." But "Further verification of this method in plant practice is necessary to demonstrate its practical importance."

Some Trouble-Makers in Reservoirs

By Ralph H. Holtje

WHEN a physician is called upon to treat a person who has been attacked by a pathogenic organism, he bases his treatment upon the knowledge he has gained about that specific organism. He knows its life history, what effects it produces and probably how, when and where it first attacked the patient.

The engineer, in the same sense, when confronted by a heavy growth of algae in an open reservoir, *must* know with what particular alga he is dealing to treat that water intelligently. The trouble caused may be color, turbidity, decreased filter runs, or tastes and odors. Too often he is forced to increase chlorine and ammonia dosages substantially and to add large quantities of activated carbon or use enormous quantities of wash water for the filters. Incidentally plant operating costs would be increased. In practically every case the trouble could have been avoided by periodic microscopical examinations of the raw water. In this way, he would know *in advance* when a particular alga is going to cause trouble by following its growth. In addition he will know what trouble to look for and what precautionary measures he should take. The best way to deal with algae trouble is to get at the source of trouble—the algae themselves—and to do this before, not after the organism has increased out of bounds.

Let us suppose the engineer does become interested in identifying and counting the algae. The first thing he notices about the algae is the long and peculiar names given them. Almost all of the names are descriptive terms in Latin or Greek. After studying the derivations and English equivalents, a working knowledge is gained in a

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A paper presented at the New Jersey Section meeting at New Brunswick, N. J., February 7, 1939, by Ralph H. Holtje, Assistant, Zoological Laboratory, Rutgers University, New Brunswick, N. J.

few weeks. The name obstacle is removed in little or no time. I will illustrate this point a little later on.

There are thousands of different species belonging to some 500 genera of algae that grow in fresh water. The engineer, however, may be concerned with *less than 30* of these. Out of the 30 trouble-makers I will consider a few of the worst offenders.

The first alga is named *Anabaena* (fig. 1), known to many water works men as "Anny." A closely related alga, *Aphanozomenon* is known as "Fanny." The Greek equivalent of *Anabaena* is "I rise, I mount, I go up." The name describes the fact that most *Anabaena* rise to the surface of the water and float there. The plants are bouyed up by the presence of many gas sacks or vacuoles in each cell.

Anabaena can be distinguished from all other algae by the blue green color, the rounded cells and the bead-like filaments, which are naked or enclosed in a thin sheath. (*Nostoc*, a closely related alga always has contorted filaments enclosed within a gelatinous mass.) The filaments may be straight or curved according to species and they may float singly in the water or form a spherical pea green colony the size of a pea. When *Anabaena* grows in a body of water, the water takes on a soapy pale blue-green appearance. As the growth increases a scum is formed as if pea green paint was floating on the surface of the water. Besides the unsightly appearance of the reservoir, the tastes and odors produced in the water may be moldy or grassy. Upon increasing growth the odor changes to nasturtium and ends with a pig-pen odor as the algae decay.

I had an interesting experience with "Anny" last summer. As hydrobiologist for the New Jersey State Department of Health I was sent to investigate a pond in a cow pasture near a seashore town. The dairyman claimed that several cows drank the water in the pond and became sick. One died. As was suspected, "Anny" was present but the growth had almost entirely disappeared by the time I was called. In Minnesota there have been almost a dozen cases where herds of cows, sheep and horses have been completely wiped out by *Anabaena* growths within 2 or 3 hours after drinking.

Chemists working on these cases could not identify the lethal substance but stated that the substance "can exist in the water around the algae, for the liquid separated from the algae is toxic." I mention this New Jersey case to illustrate the possibilities of *Anabaena*. To my knowledge, blue-green algae—or any other type of algae—have never killed any person, but we have to be on the lookout for that remote possibility. There is always a first time. Gastro-intestinal disorders have been laid to water supplies which apparently are

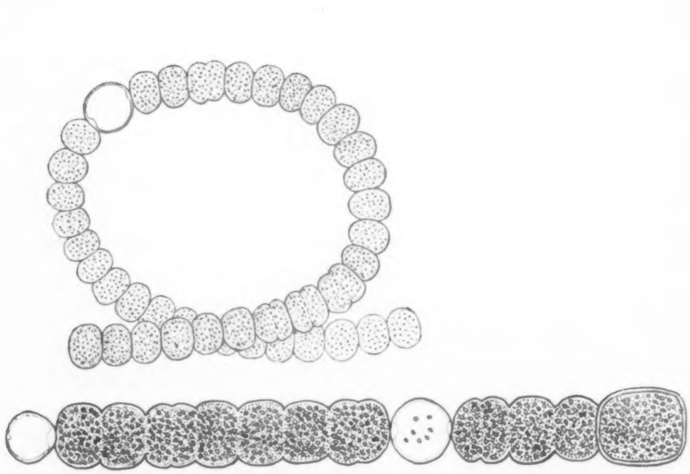

Fig. 1. *Anabaena limneticus* (left) and *Anabaena flos aqua* (right), × 600

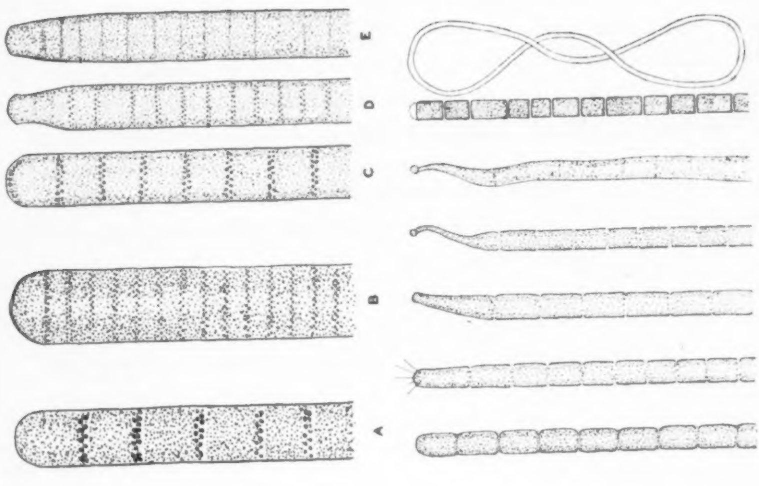

Fig. 2. (A) *Oscillatoria chlorina*, (B) —*limnosa*, (C) —*princeps*, (D), (E), (F), (G) —sp.?, (H) —*amoena*, (I), (J) —*splendida*, (K) *Phormidium fragile*, and (L) *Spirulina duplex*, × 1,200

unpolluted. Is it possible that particularly susceptible persons may be affected by water in which *Anabaena* has grown?

Another blue-green alga that has caused trouble is *Oscillatoria* or *Oscillaria* (fig. 2). A colloquial nickname is "Oscar." The name—directly from the Latin—describes the oscillation of the filaments back and forth in the water. Trouble is caused in the summer when thick mats grow on the bottom. Gases trapped in the intertwined filaments often tear portions from the bottom and bouy them to the surface. Here they rot and cause odors in the water and the air above the water. *Oscillatoria* has also grown in profusion under ice causing taste and odor troubles.

It is interesting to note here that all blue-green algae are not that color. The brown species occur in cold water, especially springs. It is said by historians that the Red Sea owes its name to a reddish growth of *Oscillatoria*.

The next organism to be considered is called *Asterionella* (fig. 3)—in Latin is little star. "Nelly" is a good nickname. It may be differentiated from all other members of its class, the Diatoms, by noticing the star formation of the individuals. By looking closely, anyone can also eliminate other radially grouped diatoms by observing that the attached end is always larger than the free end. *Asterionella* can be expected to grow in every reservoir in New Jersey at any time of the year. Peak growths usually occur in spring and fall.

Control of this diatom is an excellent example of how an engineer can *predict* algae troubles. Dr. Frank E. Hale, of New York City's Water Supply System tabulated the following statistics.

When there are 400 to 800 frustules per c.c., the odor is earthy and complaints few;

When there are 800 to 1,600 frustules per c.c., the odor is geranium and complaints numerous;

When there are 1,600 and over frustules per c.c., the odor is fishy and complaints general.

Now we come to the real trouble-makers, those belonging to the golden-brown class of algae. These are *Dinobryon*, *Uroglenopsis* and *Synura*. In order to increase familiarity with these organisms, they may be called "Dinny O'Brien," "Topsy," and "Sinner." Anyone who has battled an infestation of *Synura* will grant the term "Sinner" without debate.

Dinobryon (fig. 4) is a very descriptive name derived from the Greek words din and bryo which literally mean whirling moss. This alga is usually recognized by its colonies of urn-shaped shells or loricae which are transparent. The lorica is open and flared at one

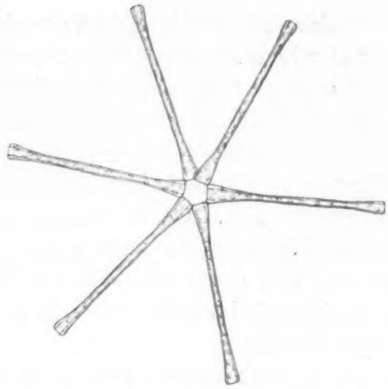

FIG. 3. *Asterionella formosa*, × 300

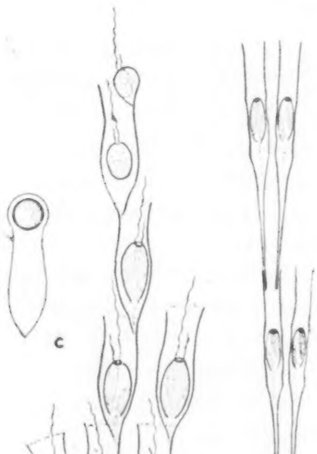

FIG. 4. (A) *Dinobryon sertularia*, (B) —*bavaricum*, (C) —*sertularia* (cyst), × 600

end while the other end tapers to a point. Except for the pointed end, the lorica is shaped very much like the old-fashioned glass kerosene-lamp chimney. The colonies consist of the loricae that are inserted one in the other. The brown zooid within each shell is equipped with two hair-like processes called flagella which whip through the water and cause the rotating motion of the colony.

Dinobryon may be expected to reach its peak of productivity in the spring and fall. Depending upon the number of colonies present, the odor produced at first is aromatic. With increased growth an odor suggestive of violets is produced. A very heavy growth will produce fishy odors. At this time the water in the reservoir will have a brown muddy color.

Uroglenopsis (fig. 5), referred to in older literature as *Uroglena* has been given a Greek name. A little imagination was used to coin it. Uro means tail, glen means cavity and ops stands for appearance. Putting these together *Uroglenopsis* describes a hollow alga propelled by flagella or tails. A colony is made up of 100 to 1,000 brownish cells that are arranged on the surface of a sphere. Each cell or zooid is equipped with two whip-like flagella.

Most growths of *Uroglenopsis* ("Topsy") come and go within a few days, but the tastes and odors produced often linger in the water for a week or more. These odors have been variously described as fishy, oily—even like rotting cabbage—and are accompanied by a cod-liver oil taste.

Uroglenopsis is exceedingly delicate and may be destroyed by a slight turbulence of the water. The sample taken from the reservoir suspected of having *Uroglenopsis* should be examined within a few minutes because disintegration starts as soon as the natural environment is disturbed. Any engineer who has had taste and odor trouble due to *Uroglenopsis* has found this unpleasant cod-liver oil taste will result even if only 3 or 4 colonies per liter are present.

The last organism to be described is called *Synura* (fig. 6). The Greeks, again, had a word for it. Syn indicates similarity, while ura indicates a tail. This is not apparent at first but it happens that *Synura* is propelled through the water by means of two similar tails or flagella on each cell.

This organism grows in colonies of from 2 to 100 cells arranged radially about a common center. The colony resembles a cluster of apple seeds with their pointed ends fused together. It has a characteristic brisk rolling motion that makes its identification easy.

Synura is probably the worst single trouble-maker in water im-

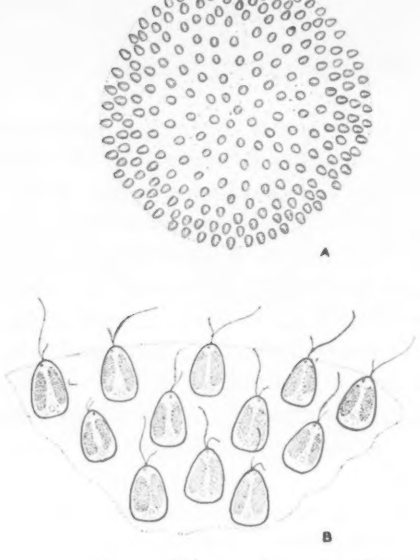

Fig. 5. *Uroglenopsis americans*, (A), a colony, × 150, and (B), section of colony, × 600

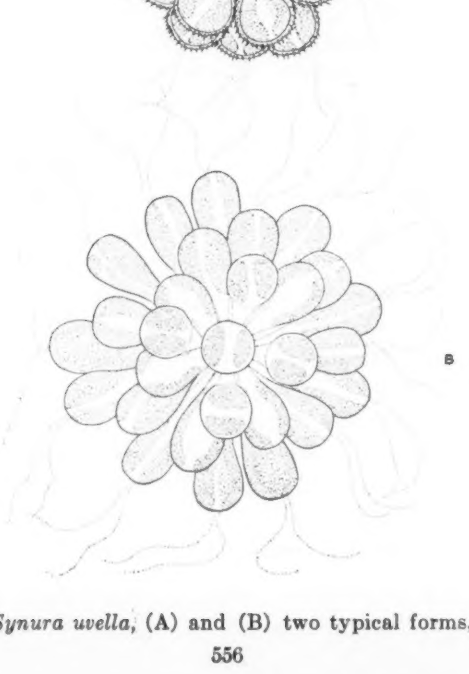

Fig. 6. *Synura uvella*, (A) and (B) two typical forms, × 600

pounding reservoirs. Only a few colonies per c.c. produce odors that have been described as cucumber, muskmelon and fishy. The taste produced affects the back part of the tongue and is bitter. The source of the objectionable tastes and odors is oil globules that are stored in the cells as food reserves. When the cells are broken it is this oil, liberated into the water, that causes trouble.

Work has been going on at Rutgers University under Doctor T. C. Nelson for many years in an attempt to determine the factors that cause the growth and death of *Synura* and other organisms in water. Its habits are becoming better known with each investigation. We now know that *Synura* tends to concentrate at a depth of one meter from the surface. In many cases a reservoir need be treated with copper sulfate for only the upper two meters of the reservoir. Furthermore, reservoirs equipped with variable-depth intakes, can be drawn upon from depths other than where the organisms are known to be concentrated.

We have studied the effect of rainfall upon the growth of *Synura*. Data collected indicate, with many exceptions, that rainfalls immediately precede the initial occurrence of *Synura*. Furthermore, heavy rainfalls are followed by a rapid increase in its growth-rate. There is a short lag caused by dilution.

Again, by keeping records of the temperatures as well as of dissolved oxygen, free carbon dioxide and other observations at various depths in the reservoir, we can actually predict the probable start of a growth of algae. I make reference here to the annual or semiannual "turn-over" of many reservoirs in the fall and spring.

In the study of temperature changes we are lead to believe that a drop in the temperature of the water brings about an increase of *Synura*. This is particularly true if the temperature drops through that portion of the centigrade scale between 10 and 13 degrees. There is also evidence that *Synura* has a lower critical temperature near the freezing point of water, since trouble-producing growths have occurred under the ice. Stated differently, we are trying to verify the theory that changes in temperature set off chemical "time-clocks" within the dormant cells and cause reproduction and growth.

In conclusion, I would like to point out the value to the engineer of being familiar with the habits of the algae. First, he can take steps to prevent heavy algae growths in reservoirs or at least be prepared before serious trouble starts. Second, he can insure himself against sudden changes in the palatability of the water. And third, he will be able to affect considerable savings on any or all adjusting agents used at the plant or reservoir in combating algae trouble.

Progress in Lime–Soda Water Softening

By George A. McBride

THE first intentional lime water softener was probably made of glass. This seems likely because it was Cavandish the chemist who, in 1766, found that lime would bring about precipitation of calcium and magnesium from water solutions. No doubt his equipment was a test tube but, in 1841, Clark and Porter in England carried the reactions into larger scale operation and obtained patents on their process. Thus the batch system of lime and soda water softening made its entrance into industrial practice. It was characterized by the following steps in treatment: (1) filling the tank, (2) mixing the chemicals, (3) coagulating the precipitate by additional slow agitation, (4) settling, and (5) drawing off the clear water to use and removing the sludge.

Many difficulties were encountered in early batch operation and the consequences of these had to be met as they occurred. Mechanical stirring, of course, developed with all sorts of paddle shapes and conditions of agitation. Air was sometimes bubbled up through the tank to effect a mixing of the chemicals and the water. But, regardless of process and equipment, all the plants were troubled by "after-deposit" in distribution ducts and piping; in fact, everywhere the treated water contacted a surface of any kind, the reaction products would adhere, crystallize and eventually so fill the pipes or ducts that frequent cleaning or replacement was necessary. Even though the treated water might appear to be quite clear, the "after-deposit" continued to offend whenever the water was used too soon.

To overcome the "after-deposit" the excelsior filter was developed and, by presenting a large amount of surface on which precipitation could take place, gave a measure of improvement. Certainly what precipitated out on the excelsior was not available for later precipita-

A paper presented at the Wisconsin Section meeting at Milwaukee, Wisconsin, October 11, 1938, by George A. McBride, Chemical Engineer, International Filter Co., Chicago, Ill.

tion and, to this extent, better results were obtained. The excelsior itself quickly became coated and had to be replaced frequently.

Sand filters came later, giving still further relief, but not perfection, because the precipitation tended to take place on the sand grains, cemented them together and eventually necessitated the replacement of the sand. Conditions were aggravated by lack of understanding of sound filter design which would have provided good distribution of wash water and the other fundamentals so necessary to bring about cleansing of the sand bed.

The chemists and operators of these batch plants could not help but feel that their troubles were largely due to incompleteness of precipitation. They found that more complete mixing and a longer retention time seemed to give better results. Holding over some of the solid precipitate from the previous batch seemed likewise to help the situation. The impression was justified that the materials were slow to react and precipitate in a size or mass great enough to settle rapidly and separate completely. Out of these experiences there grew certain ideas of the importance of providing sufficient retention time. It is worthy of note that progress in lime soda softening down through the years has been characterized by successive reduction in this time of retention and, from the standpoint of cost of construction, the validity of this criterion of progress can be appreciated.

Industrial Development Forced Softening Efforts

Under the pressure of industrial development in the early part of this century, the importance of soft water in large quantities was realized and the limitations of even multiple tank, batch systems were recognized. Continuous softening processes made their appearance but were held back in their quick development by the deficiencies of the early continuous feeding and water control equipment. Hydrated lime as a commercial product was unknown in those days and the operators had to prepare their own solution of lime, or "lime water" as it was called. An impressive number of different schemes were resorted to to effect a proportioning of treating chemicals to the flow of water, some of which were successful in varying degrees. In all the old continuous processes, however, the three important elements of the old fashioned batch system persisted. These were mixing, coagulating and settling; only filling and drawing down of the tank were eliminated.

In the continuous large scale softening operations, mixing was quite

often deficient. This can be readily understood when the volumes and masses of water concerned are given a bit of consideration. Many installations sought to drive special mixing devices from the incoming water and it is not surprising that special, independently driven means for obtaining quick mixture of the large quantities of water and treating chemicals were developed in the course of time. Considerable benefit resulted from these improvements for, after all, softening chemicals cannot react with water unless they are intimately mixed therewith.

Once mixing was complete and reactions were started, it was not sufficient in these large old-time plants to let it go at that. The precipitates formed had to be slowly mingled so that they could tangle up with each other and so that their surfaces were made available for precipitation of new reaction products as the latter formed. Reaction in the old type of plant is still taking place after mixing is complete. Lime does not go into solution very readily, and with even more than the required quantity of water to permit complete solution, commercial lime does not dissolve in water nearly as rapidly as desirable. At the end of an hour of continuous agitation there is still some undissolved lime, which, in the old practice, settled on the bottom of the tank and was ultimately withdrawn to waste.

When chemicals dissolve in water they are really just tremendously subdivided so that their individual elements or radicals are dispersed or distributed in the water. It may be assumed that the particles of precipitate formed by reaction of the radicals with each other are, at the instant of reaction, tremendous in number and extremely small in size. A chemist would term them "molecular."

Mixing Reduced Retention Time

Unnumbered millions of particles so small as to defy the microscope are, then, the first state in reaction. Their presence cannot be detected by the eye and even after considerable increase in their size by junction of numerous crystals with each other, there are still many of them in such a state of subdivision that they cannot be seen. The condition is sometimes spoken of as being colloidal; but another term, "supersaturated" has been suggested because of the tendency of these water softening precipitates to stay in solution in concentrations greater than their normal solubilities. These very small particles originally formed must and do grow by precipitation of newly formed and supersaturated material on them. They all start

from scratch, in a manner of speaking, and they have a long distance to go in size before they get large enough or heavy enough to settle out with any practical speed. It is bound to take time to accomplish this "agglomeration" and it is understandable that long times of retention and mixing were bound to be an advantage in the old practice. Adequate mixing and careful coagulation, then, permitted progressive reductions in retention time until times as short as four hours became satisfactory from the standpoint of results.

About 20 years ago, two important things happened to the lime-soda softening process. Recarbonation was known in England some years before, but came into application of widespread importance in this country at about this time. Recarbonation is simply treatment of the water with carbon dioxide. It reacts with the calcium carbonate and magnesium hydrate which tend to remain in supersaturated condition and to deposit on the filter sand or in the distribution system, converting them into soluble compounds.

The importance of the development of recarbonation can be realized when it is considered that the growth of "after-deposits" in distribution systems was largely responsible for the slow development of water softening in this country. By proper recarbonation, the aggravation and cost attending the plugging up of meters and distribution systems could be, and were, reduced or avoided.

Sludge Return Processes Introduced

The other important advance was the introduction of sludge return processes in which the writer's company pioneered. In order to realize its significance, it is necessary to return to a consideration of supersaturated solutions.

Behrman and Green, in their recent paper, entitled "Accelerated Lime-Soda Water Softening" (Ind. Eng. Chem., **31**: 128 (1939)), have described the conditions in the following words:

"In the lime-soda process of water softening, the calcium of the raw water is precipitated as calcium carbonate and the magnesium as magnesium hydroxide. This is true when lime alone is used as the precipitant, or when both lime and soda ash (sodium carbonate) are utilized.

"It follows that, if the reactions involved could be carried to completion, the hardness of the raw water would be reduced to a value equivalent to the combined theoretical solubilities of calcium carbonate and magnesium hydroxide. This combined value is approxi-

mately 20 to 25 parts per million (expressed as calcium carbonate) in pure water, and a little less at the high pH environment (typically 10.5 to 11.5) characteristic of lime-soda softening.

"In actual practice, however, this theoretical efficiency of precipitation is not achieved, particularly when the softening process is carried out in the cold, as is necessarily the case in softening the water supply of an entire community or for industrial processes in which cold water is required. Until a relatively few years ago, before modern softening equipment became available, a reduction in hardness to 70 or 90 p.p.m. (as calcium carbonate) was considered satisfactory performance in cold process softeners, even when a large excess of reagents was employed; and until quite recently an effluent hardness of 50 or 60 p.p.m. represented efficient softening, likewise with the use of an excess of reagents.

"The discrepancy between the theoretical possible residual hardness of 20 to 25 p.p.m. and the considerably higher values obtained in actual practice has generally been ascribed in the past to the presence of unprecipitated "colloidal" calcium carbonate and magnesium hydroxide. The present writers consider it possibly more accurate and certainly more convenient to hold responsible for the discrepancy the formation of relatively stable supersaturated solutions of calcium carbonate and magnesium hydroxide."

Supersaturated solutions are not uncommon. Clear sugar solution at high concentrations, for instance, can be perfectly clear to the naked eye, but when inoculated with a sugar crystal, or, for that matter, with a speck of dust, they will quickly throw out or precipitate the excess of dissolved sugar as sugar crystals. Inoculation plays some part in initiating separation by precipitation but, in dilute supersaturated solutions such as obtain in water softening, simple inoculation is by no means entirely sufficient to attain the desired results.

Even multiple inoculation alone is insufficient but, in conjunction with proper agitation to provide contact, much benefit results. Thus, if a tremendous quantity of surface is provided, the mass effect of this area becomes available and can be made *effective* by proper conditions of agitation. Under these conditions, removal of the supersaturated material takes place much more quickly, While inoculation contributes, good contact through proper agitation is very important. It is on these principles that the sludge return processes were based.

In sludge return, previously precipitated sludge was picked up by one means or another and returned to the mixing chamber of the softener. The agitation brought about contact of the tremendous surface of the sludge particles with the supersaturated material and served to greatly hasten the completion of the chemical and physical reactions. There were disadvantages to the sludge return process. The means of putting back the solids into the mixing system were extremely important. It was difficult to handle the precipitate without destroying some of the bundles of particles which had been so carefully formed in coagulation, and this destruction naturally placed a heavier load on the settling equipment.

Even in the sludge return process the three important stages of the old process, i.e., mixing, coagulation and settling, were still apparent as definite steps. While still retaining these steps or stages of treatment and their disadvantages, the sludge return process first pointed the way toward research work and development which ultimately resulted in the Accelator process which is described in detail below.

Perhaps the highest development of the old process of mixing, coagulation and settling is to be found in the recently developed Spaulding apparatus wherein long periods of mixing and coagulation are provided and conventional settling replaced by a form of delayed sedimentation which greatly aids clarification. Spaulding makes use of a tapered tank of increasing cross-section which serves to maintain a bed of precipitated solids in suspension through which the carefully coagulated water percolates upwardly and from which the heavier solids deposit on the inclined surfaces to drop ultimately into the lower portion of the tank where they are stirred to prevent compacting before periodic withdrawal to external concentrators or to waste.

In the Accelator process, as differentiated from the older processes which have been discussed up to this point, the three stages of mixing, coagulation and settling are replaced by a single stage carried out in a single vessel. True, there is mixing, and well-coagulated slurries certainly result; but these steps take place simultaneously within the same vessel and cannot be differentiated one from the other. From the slurry, the clarified and treated water is separated but, in no sense of the word, by sedimentation. Solids just do not settle in this type of equipment, rather they are skimmed off the top of the circulating slurry into an integral concentrator from which they are removed as high-solids-content sludge.

Figure 1 shows a form of tank in which the process may be practiced. This tank typically has about the same free area as the filters it serves. The processing and results, represented by the old mixing, coagulation, and settling processes, are all carried out in this vessel. The prerequisites are proper control of water and chemical supply. The effluent may be recarbonated and filtered as required.

Attention is directed to the primary mixing and reaction zone (shown in fig. 1) in which the chemicals are first added to the returning slurry and mixed with it before water enters the system. This kind of treatment overcomes the disadvantage of the old processes wherein millions of tiny, colloidal particles are formed by the interaction of the chemicals and raw water. In the unit, raw water meets

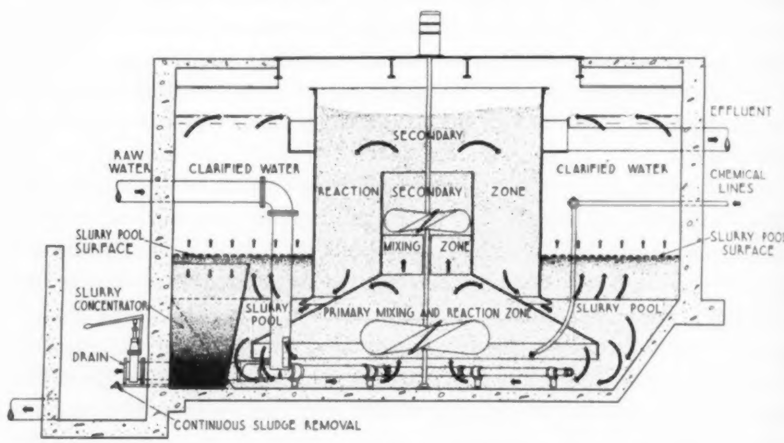

FIG. 1. Cross Section of Typical Accelator Water Softener

the chemically treated slurry and the reaction products precipitate on the surfaces of the sludge particles existing in the slurry. Reaction of water with its aliquot portion of treating chemicals does not result in millions of colloidal particles, and particles growth does not have to start from scratch. As a consequence, the slurry transferred through the secondary mixing zone into the secondary reaction zone is already well conditioned and, if it were permitted to do so, would settle very rapidly. Transfer of the slurry from the secondary reaction zone into the slurry pool takes place under the head created by the transfer propeller. This flow is generally three or more times the volume represented by the flow of treated water through the unit and, as a consequence, there is a positive sweeping wash effect

maintained which prevents deposition of solids on surfaces in the lower portion of the tank. In proportion to the quantity of raw water supplied, an equal portion of treated water is displaced from the slurry pool and rises to the clear water launders.

The character of the slurry is such that water separates from it at remarkable rates. It is not at all unusual to obtain clear water from the surface of this pool at rates of 3 or more gallons per sq.ft. per minute of free area. The capacity of the unit is limited only by the rate at which clear treated water may be withdrawn from the slurry pool and it should, by now, be quite clear that retention time has no place or value in setting the capacity of a unit of this type. Time does not have to be allowed for coagulation because precipitation has instead taken place on the slurry particles and once water is separated from the slurry pool, additional time is of no value.

It can be readily seen that this separation of clear water from the slurry pool is something quite different from the old "sedimentation" involved in previous practice. Whereas a gradient of solids concentration may exist in one of the old settling tanks or basins so that the concentration of solids at one level is considerably different from that at another level, the situation is quite different in this system. The water is literally squeezed out from the surface of the slurry pool because the masses resulting from the compounded precipitation are too heavy to be carried up the tank by the buoyancy of the rising clear water. For this reason, it is not at all unusual to stand on top of this unit in operation and look down through six or seven feet of clear water to see the billowing surface of the slurry pool which appears to be almost a white blanket from which clear water is continually emerging. The top surface of this pool is sharply defined and samples taken from the tank may show several per cent of solids at a level just below the surface of the slurry pool, whereas samples taken a few inches above will contain only a few parts per million of suspended solids.

To sum up the action of this slurry, it may be said that by adding the chemicals to the slurry and then mixing in the water there is produced such a condition of accelerated chemical and physical reaction that complete mixing is practically synonymous with full benefit of treatment. Soluble treating reagents are reacted immediately and the products of reaction removed from a state of supersaturation by the agitation with the tremendous surface of precipitation offered by the slurry. In accordance with the laws of mass

action, this removal of colloidal material permits the reactions to proceed at faster rates and more completely.

The proof of the pudding is in the eating thereof; so, figuratively speaking, the value of the Accelator's contribution to lime and soda softening may be evaluated by the results obtained. The operating data already accumulated on more than 35 installations indicate that the full benefit of softening attainable in old type four-hour systems is obtained in this unit and, most important, in very much less time.

This type of results is especially impressive when it is considered that they may be obtained in a unit having a throughput based on a 3 g.p.m./sq.ft. per minute rising rate which generally means that the total free area of the unit is usually about the same as the area of the filters provided for industrial applications and can be considerably smaller in area than filters provided for municipal work. It is interesting to notice that capacity rating of these units is in many ways analogous to the standard rating of filters in that they, too, are based upon gallons per sq.ft. of free area.

These softeners need, then, but little space and can be fitted into existing plant facilities with a minimum of floor space and head room requirements. The savings obtainable by use of these efficient tanks can be quite impressive, especially when referred to the old criterion of retention time. Accelators seldom have a retention time of more than 35 to 40 minutes (and sometimes considerably less).

It is apparent from fig. 1 that the retained solids are circulated over and over again, each time increasing in mass and improving in condition until an optimum condition of slurry is attained. Lime not yet dissolved and still unreacted is circulated over and over again until its full value for treatment of the water is exhausted. This fact accounts for an efficiency in which the lime used closely approaches the theoretical and so considerable expense is saved in the course of a few years' operating time. The sludge removed from one of these softeners will show only a trace of unused chemical.

As this unit starts operation without previously accumulated solids, the return circulation brings about accretion on the first formed particles, and they grow to form the conditioned slurry on which the unit depends for its action. Shutting down the softener for varying periods of time is common practice; and it is quite satisfactory to use this type of operation, because the efficient circulation provided in the reaction zone very quickly resuspends the solids on resuming operation. Circulation and mixing in the primary reaction

TABLE I*

Condensed Typical Operating Data

	ACCELATOR WATER SOFTENER[1]				
	A	*B*	*C*	*D*	
Treating capacity, gal./min.:					
Rated	600	600	500	26	
As operated	350	650	200-500	32-26	
Flow rate, gal./min./sq. ft.:					
As designed	1.12	1.85	2.2	2.00	
As operated	0.65	2.00	0.86-2.2	2.46-2.0	
Retention time, min.:					
As designed	66	61	48	39	
As operated	114	56	48	33-39	
Raw water characteristics, p. p. m.:					
Turbidity	2	10	2	640	1250
Total hardness (as $CaCO_3$)	300	350	370	106	102
Calcium hardness (as $CaCO_3$)	222	160	280	84	78
Magnesium hardness (as $CaCO_3$)	78	190	90	22	24
Total alkalinity (as $CaCO_3$)	266	370	314	74	61
Free carbon dioxide	15	16	27	..	..
Effluent from accelator, before recarbonation or filtration, p. p. m.:					
Turbidity	3	5	10	10	10
Total hardness (as $CaCO_3$)	85	112	97	68	50
Alkalinity (as $CaCO_3$):					
Phenolphthalein	31	83	10	15	23
Methyl orange	46	124	45	30	37
Chemicals used for treatment, lb./1,000 gal.:					
Hydrated lime [approx. 90% available $Ca(OH)_2$]	2.24	3.66	1.78[2]	0.84	0.92
Soda ash (98% Na_2CO_3)	0.053	0	0	0	0.44
Aluminum sulfate (filter alum)	0.106	0.145	0.07	0	0
Ferric sulfate (Ferrisul)	0	0	0	0.25	0.25

* From "Accelerated Lime-Soda Water Softening" by A. S. Behrman and W. H. Green, published in Industrial and Engineering Chemistry, **31**: 128 (1939).

[1] *A*, Anna, Ill.; *B*, Williams Bay, Wis.; *C*, Georgetown, Texas (no recarbonation); *D*, demonstrator Accelator water softener, Baton Rouge, La. (no recarbonation or filtration).

[2] Equivalent of the 1.35 pounds quicklime actually used when these tests were made.

zone are maintained by the lower propeller which is designed to give maximum agitation and contact. Were the precipitates of the

condition usually found in the old type of softener, it would hardly be permissible to operate the mixing and transfer propellers at peripheral velocities much greater than $1\frac{1}{2}$ or 2 ft. per second. However, a reliable idea of the toughness and resistant character of slurry particles in this softener is gained from the fact that these propellers often have peripheral velocities as high as 15 ft. per second with corresponding advantage in the effectiveness of contact of which we have spoken before. The mixing propeller is located above any settled sludge and being of moderate diameter as compared with some mixing devices, there is no danger of overloading the drive motors or of shearing the drive shaft when resuming operations after a shutdown.

The Accelator slurry generally contains between $\frac{1}{2}$ and 2 per cent of solids by weight. The amount depends on the character of the water being treated and the extent of treatment. Calcium carbonate and magnesium hydrate are quite different in their physical characteristics and the physical character of the slurry formed in a softener will depend, among other things, upon the proportion of these materials precipitated under any given operating condition. Suffice it is to say that a certain concentration of slurry characterizes each condition of operation and fixes the concentration of solids in circulation. When more than that quantity of solids necessary for proper treatment is precipitated, the excess simply expands into the portion of the tank immediately above the slurry pool and, when the level of this expanded slurry reaches the top of the concentrator, the excess solids flow over into the concentrator from which they may be removed as a rather heavy sludge.

The concentrator is an important feature of this system. In simple terms, it is simply a chamber, usually within the tank, in which there is no circulation and through which there is no velocity or buoyant effect of rising treated water. As a result, the solids skimmed off over its edge settle into the concentrator; compact by reason of their tendency to settle; and, are drawn off at concentrations considerably greater than exist in the circulating slurry. The concentrator is usually integral with the unit construction and in no way interferes with the effective area from which clear water may separate. By means of the concentrator there is maintained a continuous removal of excess solids while still assuring an adequate supply of slurry for action. The concentrators require no extra

tankage external to the unit and, consequently, no additional pumpage of water or sludge.

The fact has been mentioned previously that no sedimentation is permitted in this softener. A direct advantage arises from this fact. Consider for a moment that in an old type settling basin or clarifier, the solids are expected to settle and accumulate to the depth of several feet. As compared with this particular equipment in which, perhaps, 25 per cent of the total small volume of the tank contains a slurry of 2 per cent solids by weight, a conventional basin may contain several feet of settled solids of 20 or 30 per cent by weight. Whereas this unit may, then, retain the solids of only a few hours operation, the conventional basin may have the solids of several days or even weeks of operation. Because of the continuous addition to and removal of solids from the unit the precipitated matter is in contact with treated water for a relatively short time and unpleasant tastes and odors from sludge putrefaction are much less likely to occur.

An important mechanical feature deserves mention here. Many will recall difficulties with bearings and chains operating in abrasive water softening precipitates in quick mix, coagulating and sludge scraping mechanisms. For those who have experienced such troubles, the single water-washed bearing of this circulating mechanism will have a special attraction and all will recognize the advantage of only one bearing from which grit is excluded by positive water pressure. The fact that this bearing is rigidly attached to the same structure to which the motor drive is fastened simplifies alignment of bearings and ensures that, once aligned, they will stay there.

This new process offers advantages in size, in cost (both installation and operating), in chemical and mechanical economy, in simplified construction, operation and maintenance, in flexibility and in possibilities of architectural beauty of line and mass. This softener warrants careful consideration for any water treatment project.

Report of Audit of Association Funds For Year Ending December 31, 1938

To the members of the American Water Works Association:

The By-Laws require that the Secretary shall have made an annual audit of the books of the Association.

The records for 1937 have been examined by the staff of Louis D. Blum & Co. The complete record of that examination follows.

Reference may be made to the audit for 1937 which appeared on pages 520 to 525 of the JOURNAL for March, 1938.

There is also submitted a membership statement for 1937 and a comparative record for 1929–1938 inclusive.

Respectfully submitted,

HARRY E. JORDAN, *Secretary.*

February 6, 1939

Mr. Harry E. Jordan, Secretary,
American Water Works Association
22 East 40th Street,
New York, N. Y.

Dear Sir:

The audit of the books of account of your Association for the year ended December 31, 1938 has been completed and as a result thereof we submit the following described exhibits and schedule:

Exhibit A—Balance Sheet, December 31, 1938

Schedule 1—Investments—At Cost December 31, 1938

Exhibit B—Statement of Income and Expenses for the Year Ended December 31, 1938

Exhibit C—Surplus Account for the Year Ended December 31, 1938

The balance sheet includes proper accruals for receivable and payable items as at December 31, 1938.

Increases in surplus as shown in Exhibit C represent the net income for the year per Exhibit B and profit realized on the redemption of New York Steam Corporation bonds.

We wish to take this opportunity to thank you and your staff for the cheerful coöperation and the many courtesies extended to our representatives during the course of our examination.

Very truly yours,

LOUIS D. BLUM & CO.,
Certified Public Accountants.

EXHIBIT A

Balance Sheet, December 31, 1938

Assets

Cash in bank and on hand		$18,132.28
Notes receivable		20.40
Accounts receivable:		
Advertising	$3,095.13	
American Public Health Association	997.71	
Water Works Manufacturers Association	422.92	
Reprints	192.84	
Manual of Water Works Accounting	81.89	
Manual of Water Works Practice	10.00	
Royalties on Manual of Water Works Practice	19.00	
Sundry	15.19	4,834.68
Membership dues		226.55
Accrued interest on bonds and notes		326.75
Inventories:		
Type metal	$458.63	
Manual of Water Works Accounting	118.90	
Manual of Water Works Practice	11.25	
Index	132.30	
Specifications	77.64	
Census	8.75	
Membership certificates	55.43	
Brochure—Fuller Memorial Award	82.77	945.67
Office equipment	$5,955.97	
Less: Reserve for depreciation	2,772.67	3,183.30
Investments, per schedule 1—at cost		39,251.11
Total assets		$66,920.74

Liabilities and Surplus

Accounts payable	$2,199.52
Membership dues—Advance payments	9,049.10
Unearned subscriptions to Journal	1,222.89
Surplus, per Exhibit C	54,449.23
Total liabilities and surplus	$66,920.74

EXHIBIT A, SCHEDULE 1

Investments—At Cost, December 31, 1938

SECURITY		PAR VALUE	DATE OF MATURITY	PURCHASE PRICE
Alabama Power Co.	4½s	$2,000.00	1967	$1,932.50
City Los Angeles, Water Works bonds	3½s	2,000.00	1960	2,241.11
International Tel. & Tel.	5 s	3,000.00	1955	2,895.00
New York City Corporate Stock	4¼s	2,000.00	1956	1,990.00
New York City Corporate Stock	4¼s	2,000.00	1961	1,995.00
New York City Corporate Stock	4¼s	2,000.00	1963	1,990.00
North American Edison	5 s	2,000.00	1969	1,915.00
Province of Ontario	4½s	2,000.00	1946	1,690.00
Province of Ontario	4 s	1,000.00	1964	732.50
Province of Ontario	5 s	3,000.00	1942	3,105.00
Province of British Columbia	4½s	1,000.00	1951	1,000.00
Southern Pacific	4½s	5,000.00	1977	4,875.00
United States Savings Bonds		*5,390.00	1947	5,390.00
United States Savings Bonds		**7,500.00	1948	7,500.00
Totals		$39,890.00		$39,251.11

* Value of bonds at maturity date, May 1, 1947, $7,000.00. Includes $140.00, interest accumulated since date of issue.

** Value of bonds at maturity date, December 1, 1948, $10,000.00.

EXHIBIT B

Statement of Income and Expenses for the Year Ended December 31, 1938

Operating income:			
Annual dues		$34,816.02	
Advertising		22,508.00	
Subscriptions to journal		3,240.26	
Convention registration fees		4,964.00	
Convention extra tickets		1,539.00	
Water Works Manufacturers Association		7,500.00	
Interest on investments		1,521.67	
Interest on deposits and notes		22.13	
New Orleans Water Board		1,500.00	
John M. Goodell prize		75.00	
Total operating income			$77,686.08
Development income:			
Sales of "Manual of Water Works Practice"		$250.00	
Royalties on "Manual of Water Works Practice"		38.00	
Sales of "Manual of Water Works Accounting"		722.14	
Sales of reprints		1,641.83	
Sales of specifications		514.48	
Sales of census		7.00	
Sales of index		24.96	
Sales of proceedings		501.48	
Sales of membership certificates		12.15	
One-half of profits from sales of 8th edition of "Standard Methods of Water Analysis"		997.71	
Total development income			4,709.75
Total income			$82,395.83
Operating expenses:			
Directors' and Executive Committee Meetings:			
Travel expenses—Annual meeting	$1,973.29		
Stenographic expense	83.62		
Executive committee expense	102.01		
Total		$2,158.92	
Administrative expenses:			
Rent	$1,592.15		
Office supplies	3,191.83		
Membership promotion	618.36		
General travel expense	324.45		
Auditing and legal expense	295.00		
Membership certificates, incl. lettering and mailing	27.78		
Total		6,049.57	
Administrative salaries		24,428.54	
Committee expense		563.46	
Section and division expense:			
Division expense	$23.46		
Section—Membership allotment	3,861.50		
Section—Official travel	2,205.37		
Section—General expense	93.08		
Total		6,183.41	

EXHIBIT B *continued*

Journal:			
Printing	$19,973.00		
Abstractors	772.04		
Office assistant—Part salary for editorial work	*691.67		
Biennial membership list	*1,200.00		
Total		22,636.71	
Convention:			
General	$1,356.81		
Entertainment	5,054.94		
Management committee	289.45		
Publicity and attendance committee	43.83		
Total		6,745.03	
Membership dues in other associations		460.00	
John M. Goodell prize		70.00	
Brochure—Fuller memorial award		*3.37	
Association publicity:			
Special services	$2,500.00		
Office assistant—Part salary for publicity work	345.83		
Total	$2,845.83		
Less: Reimbursement of one-half of publicity expenses by Water Works Manufacturers Association	1,422.92		
Total		*1,422.91	
Moving expenses		*252.97	
Depreciation of office equipment		324.18	
Uncollectible accounts		175.87	
Miscellaneous expense		21.12	
Total operating expenses		$71,496.06	
Development expenses:			
Cost of publications sold:			
Manual of Water Works Practice	$189.08		
Manual of Water Works Accounting	355.30		
Reprints	1,285.40		
Specifications	300.24		
Census	16.25		
Index	16.38		
Committee expenses:			
Quality and treatment—Editing	551.00		
Hydrant and valve specifications	131.73		
Total development expenses		2,845.38	
Total expenses			74,341.44
Net income for the year—Transferred to Exhibit C			$8,054.39

* For budget purposes, your Association considered these items, with the exception of $600.00 of the charges for the biennial membership list, to have been provided out of 1937 surplus.

EXHIBIT C

Surplus Account for the Year Ended December 31, 1938

Balance, January 1, 1938		$46,255.56
Add:		
Net income for the year, per Exhibit B	$8,054.39	
Profit realized on redemption of New York Steam Corporation bonds, $4,000.00 par value	139.28	8,193.67
Balance, December 31, 1938, Per Exhibit A		$54,449.23

Membership statement for the year 1938

	ACTIVE	CORPORATE	ASSOCIATE	HONORARY	AFFILIATE	JUNIOR	TOTAL
January 1, 1938	2,605	259	180	20			3,064
Gains:							
New Members	432	29	19	2	34	4	520
Reinstated	56	3					59
	3,093	291	199	22	34	4	3,643
Losses:							
Resignations and Deaths	121	10	11	2			144
Suspended for non-payment of dues	133	5	2				140
Total December 31, 1938	2,839	276	186	20	34	4	3,359
Total January 1, 1938	2,605	259	180	20			3,064
Gain in Year 1938	234	17	6		34	4	295

Comparative statement—Gains and losses—Ten-year period

YEAR	NEW	REINSTATED	RESIGNATIONS AND DEATHS	SUSPENDED FOR NON-PAYMENT OF DUES	GAIN OR LOSS	TOTAL MEMBERS AT END OF YEAR
1938	520	59	144	140	+295	3,359
1937	514	86	122	139	+340	3,064
1936	311	53	104	218	+42	2,724
1935	565	42	85	190	+332	2,682
1934	271	66	86	122	+129	2,350
1933	168	56	159	234	−169	2,221
1932	117	22	169	297	−327	2,390
1931	203	22	123	216	−114	2,717
1930	501	39	121	134	+285	2,831
1929	314	25	118	130	+91	2,547
Total 10-year period	3,485	470	1,231	1,820	+904	

ABSTRACTS OF WATER WORKS LITERATURE

Key. **30:** 402 (Mar. '38) indicates volume 30, page 402, issue dated March 1938. If the publication is paged by issues, **30:** 3: 402 (Mar. '38) indicates volume 30, number 3, page 402. Material inclosed in brackets, [ ], is comment or opinion of abstractor. Initials following an abstract indicate reproduction, by permission, from periodicals as follows: *B. H.—Bulletin of Hygiene (British); C. A.—Chemical Abstracts; P. H. E. A—Public Health Engineering Abstracts; W. P. R.—Water Pollution Research (British).*

FINANCING AND RATES

Utility Financing under the Holding Company Act. Merwin H. Waterman. Pub. Util. Fort. **23:** 195 (Feb. 16, '39). Public Utility Holding Company Act passed by 74th Congress in '35, registration provisions became effective Dec. 1, '35. Analysis and comment delayed until '38 due to insufficient volume of utility financing. Universal resistance to provisions of law during '36 and '37, and unfavorable market conditions, resulted in nation's utilities avoiding registration and financing of securities. Exchange Commission chose to test constitutionality of registration provisions of Act rather than institute general prosecutions. Holding company-dominated industry brought under SEC control by U. S. Supreme Court decision, Mar. 28, '38 upholding constitutionality of Act's registration provisions. SEC's powers under Securities Act limited to "full and fair disclosure," while Holding Company Act definitely gives SEC control over policy, practice and procedure. The Act makes it unlawful for any registered holding company or subsidiary to issue or sell any securities without declaration and positive approval of the Commission. Under certain conditions Commission empowered to grant exemption from necessities of declaration, however, Commission may attach to exemption "such terms and conditions appropriate in the public interest or for protection of investors or consumers." Issuer of securities required to set up minimum repair, maintenance, and depreciation charges, subsequent to sale of securities. Commission appears to have exercised administrative discretion, not being unreasonable. Section 7(c) of Act states, stock must be common, with par value, without dividend or asset preference, with voting rights equal to all other shares; bonds must be secured by a first lien or first lien collateral. However, exceptions may be approved "for necessary and urgent corporate purposes" if non-approval "would impose unreasonable financial burden," or if security is for refunding purposes or for financing operating company. Unsecured bonds, preferred stocks and no par shares of operating companies can be issued. SEC permits effective declaration of an issue, providing requirements 7(c) fulfilled, state authority consents, security reasonably

adapted to financial structure and earning power of issuer, and necessary or appropriate to operation of utility or holding company. SEC authorized to pass on reasonableness of underwriting terms, fees, terms and conditions of security contract in general. SEC exercises power to mould utility financial structure, dictate terms of security contracts, supervise distribution of utility securities, either public or private offerings. Working capital safeguarded and financial integrity protected by Commission rules, regulations and orders. Utilities cannot pay dividends out of capital, or unearned surplus or redeem securities against promulgated regulations. Reasonable latitude allowable for maintenance of investor return if earnings adequate for corporate capitalization on real value of assets. Discretion and judgment required by utilities, approved course must be followed.—*Samuel A. Evans.*

Financing of Sewer Systems. PIERRE DESCROIX. L'Eau (Fr.) **31:** 107 (Sep. '38). Financing of sewer systems is frequently burdensome to governmental units undertaking it. The decree of Dec. 11, '26 in effect authorizes real estate tax for providing sewers, and that of Oct. 30, '35 requires connection to sewer of all buildings located along sewered streets. Present tax has double inconvenience of being collected annually at same time as much heavier ones, and of corresponding only imperfectly to service rendered. It does not seem just to assess sewer tax against buildings having no means of connecting to sewer. Tax base should be broadened by one of the methods reported by Allton (see J. A. W. W. A. **30:** 1285 (Aug. '38)). Various American cities have adopted third procedure listed and combine sewer tax with water rate, thus making it proportional to water consumption and minimizing labor of collecting it. Charge is thus spread over year and is proportional to service rendered.—*Selma Gottlieb.*

Income from Publicly and Privately Owned Water Systems. M. A. DANTIER. Tech. Sanit. (Fr.) **33:** 210 (Oct. '38). Article discusses question of whether or not water supply systems in towns under 5,000 in pop. can be made self-supporting. In a survey of 81 communities 28% were paying their way and 72% were not. In this latter group 73.3% were earning less than 60% of their necessary expenses. Tables are given showing average rates and average consumption per house. Conclusions: the reason for this situation is heavy cost of financing; rates are not quite high enough; average rate of consumption is too low.—*Willem Rudolfs.*

Wisconsin Public Service Commission. Re Village of Pardeeville. Pub. Util. Fort. (Jan. 19, '39) P. U. R. **26:** 207. Pardeeville filed application with Commission, to transact business as water utility, construct water works system, have plans approved and rates tentatively prescribed. Financed by $45,000 mortgage bonds, $41,120 PWA grant, $49,244 WPA labor. Commission's engineer found WPA labor added excess of about $44,000, latter not permitted as a cost. Depreciable property estimate $91,000; depreciation $1\frac{1}{4}$% on $45,000 and 1% on $46,000; $820 yearly allowed on books for local and school taxes providing safe margin for bond amortization and interest. Bond return of $5\frac{1}{2}$% meets $1,800 interest requirement for first 2 years and provides

sinking fund reserve to retire principal. Annual operating expense estimate $1,050, $677 for maintenance of production and distribution properties. Total annual revenue requirement $6,044, allocated $2,200 fire protection service, $3,844 general service. Commission urges metered service, connection charges for cost of meters, charges accounted for as contributions in aid of construction.—*Samuel A. Evans.*

Municipality Operates Outside City Limits as a Public Utility. ANON. Pub. Util. Fort. **23:** 187 (Feb. 2, '39). Vermont Supreme Court held municipality operating and having a virtual monoply in county is public utility; therefore, required to furnish service. Municipality sold large quantities of its product outside its limits. Court held there must not be discrimination between prospective customers, City has not special legislative authority to operate outside limits; therefore, not entitled to special favors. Cannot take advantages without assuming liabilities.—*Samuel A. Evans.*

City Derives Authority Only From State Laws. LEO T. PARKER. W. W. Eng. **91:** 1476 (Nov. 9, '38). Municipality possesses no inherent power from State laws. Money cannot be spent for special purposes not granted by law. Franchise rights must be adhered to. Sale of water outside city limits permissable.—*Martin E. Flentje.*

Water and Large Families in Plomodiern (Finistère, France). L. DESCROIX. L'Eau **31:** 85 (Aug. '38). In Brittany water is not plentiful, and is hard to treat, sometimes being iron bearing. Numerous scattered hamlets in each commune complicate distribution. Plomodiern, with 2550 inhabitants in 640 households, has adopted a water rate with a "truly social spirit," rate being lower for large families, e.g., for min. annual rate of 50 francs, family with two children is entitled to 25 cu. meters of water and family with 10 children to 90 cu. meters. In case of insufficient water, mayor is authorized to restrict use of water for other than domestic purposes.—*Selma Gottlieb.*

WATER WORKS ADMINISTRATION

Monthly Machine Billing Materially Increases Collections. ANON. W. W. Eng. **92:** 26 (Jan. 4, '39). Increase in 11 mo. receipts of $12,360 under monthly billing over previous semi-annual method reported by Trinidad, Colo., water dept. One bookkeeping machine handles all billing and posting work on 3600 water accounts. Bills sent out monthly on mailing cards of gov. size divided into customer's receipt portion and dept's record. More detailed work handled than formerly with no increase in staff.—*Martin E. Flentje.*

Pay Water Bills at Banks. ANON. Public Management **21:** 26 (Jan. '39). "The city of San Francisco has worked out an arrangement with approximately 100 banks whereby the city will pay the banks five cents for each water bill collected regardless of the amount. Approximately 30% of the water users are paying their water bills at the banks." [At least one private water company that we know of, Lexington, Ky., has had a similar system in effect.] —*Ed.*

Arrears in Water Rates, 1932–36. ANON. W. W. Inf. Exch., Canadian Sect., A. W. W. A. **2:** B: 8: 34 (Oct. '38). Tabulation of arrears in various Canadian municipalities is given showing (a) total arrears in dollars in '32 and '36, and (b) arrears expressed as percentage of total yearly rates during years '32 to '36. Av. percentage arrears were as follows: '32, 7.2 (45); '33, 8.1 (49); '34, 8.1 (52); '35, 8.1 (51); '36, 7.9 (58), the parenthetical figures being the no. of communities for which data are given.—*R. E. Thompson.*

Control and Regulation of Pavement Cuts. ANON. Public Management **21:** 14 (Jan. '39). Pavement cuts should be kept to a min., city should require application for all street openings and approval given only after careful study to detn. necessity. Preferable that city replace paving, billing opener for costs. When streets are repaved and new sewers laid, city should consider advisability of placing sewer outside curb line and carrying extensions beyond curb line for lots on opposite side, such plan for water and gas would probably require 2 utility lines instead of one but may prove more economical in long run. Believed both city and utilities should plan ahead and present contemplated extensions, paving, etc. to everyone interested.—*Martin E. Flentje.*

Estimated Population of Continental United States and Outlying Territories and Possessions, July 1, '38. ANON. U. S. Pub. Hlth. Repts. **54:** 180 (Feb. 3, '39). The pop. of continental U. S. on July 1, '38 was 130,215,000, according to Bureau of Census preliminary estimate, an increase of 958,000 or 0.7% over the '37 estimate of 129,257,000. It is based on the number of births and deaths during the year ending June 30, '38, and the excess of immigration over emigration. Excess of births over deaths (allowing for under-registration in both cases) was approx. 916,000; the net immigration increase was approx. 43,000. That the U. S. pop. has passed 130,000,000 is significant because of the rapidly decreasing growth rate. From 1880 to 1890 annual rate of increase was 2.3%; from '20 to '30 it was 1.5% annually; '30–'38, only 0.7% annually. Decrease attributable to (1) declining birth rate and (2) decrease in net immigration. The U. S. estimated pop. from Jan. 1, '30 through July 1, '38 is given by 6-month intervals in table 1 and that of sources similarly in table 2. Table 3 gives the last estimates of the pop. by states as of July 1, '37. Table 4 shows est. pop. of outlying territories and possessions as of July 1, '30–'38. No further estimates will be released during this decade. —*Ralph E. Noble.*

Methods of Estimating Postcensal Populations. HENRY S. SHRYOCK, JR. Am. J. Pub. Health **28:** 1042 (Sep. '38). Because of sizable errors even in recently improved methods, postcensal estimates are still too inaccurate for scientific and most administrative uses. Degree of accuracy of pop. estimates of states, cities, and counties in years after Federal Census tend to vary directly with time elapsed since census, and inversely with pop. size. Arithmetic increase assumed in early estimates; apportionment method an advance; basing estimate upon contemporary data for given area another important forward step; attention now being focused upon potential sources of such data and making these more useful. Apportionment formula assumes estimated

national pop. increase divided among states and cities in ratio of share in national increase in previous intercensal decade. Estimate of national pop. made relatively accurate by considering excess of births over deaths, immigration and emigration, and correction for underregistration of births. In state and city pop. estimates apportionment method resulted in av. error of 6.88% for states, city error higher. Estimate based on elementary school enrollment data would result in errors near 4%; if proper data were available as to enrollment age, instead of grade, av. error could be reduced to 2-3%. Improvement in school statistics to give accurate data on enrollment by age in all schools corrected for actual residence would aid in better estimates, requires additional data on other age groups however, one possible source is registered deaths for specific age groups by sex and color. Estimates for cities most difficult, school statistics seem to give best results but ratio of children to pop. of all ages surprisingly variable, in '30 to '35 led to error of 6.52% for Mass. towns of 10,000 or more. Writer believes greatest improvement in methodology in future will come from exploitation of new series of contemporary data and refinement of old ones. Urges local estimates and study.—*Martin E. Flentje.*

Laboratory Facilities at Water and Sewage Plants. H. G. HANSON. Off. Bull. N. D. Wtr. and Sew. Wks. Conf. **6:** 3: 18 (Sep. '38). The primary value of a laboratory lies in the fact that it is a means of controlling a process. Records and collection of data insure proper treatment and operation of both water and sewage plants. More data of the same nature are needed if successful operation and intelligent planning are to be incorporated in future water and sewage works.—*P. H. E. A.*

Property Owner's Responsibility for Water Supply. ANON. W. W. Inf. Exch., Canadian Sect., A. W. W. A. **2:** D: 1: 1 (Jan. '39). Amendment ('38) to Ontario Public Health Act states that it shall be duty of owner of every house to provide for occupants of same sufficient supply of water for drinking and sanitary purposes and if occupant is not satisfied with wholesomeness or sufficiency of such supply, he may apply to local board of health to determine as to same. If supply is sufficient and wholesome, expense incident to such determination shall be paid by occupant, and if not, by owner; in either case such expense shall be recoverable in same manner as municipal taxes.—*R. E. Thompson.*

Propaganda for the Use of Water. BOTHO POHL. Gas-u. Wasser. **81:** 854 (Dec. 3, '38). Owing to occasional water shortage, the water works cannot always boost for higher consumption. Aim should be to reduce wastage and to divert use to an increase where it will benefit the health of the people. Propaganda for use of water should therefore work for improvement of the house installation, especially the availability of water closets and baths in every residence or apartment, even those for workers. Coöperation should be obtained from architects, building trades, plumbers, health departments, settlement organizations, etc.—*Max Suter.*

Contractor Loses Damage Suit. H. H. SEARS. Eng. News-Rec. **121:** 124 (Jul. 28, '38). In '34, earth dam was completed for reservoir at Osceola, Iowa, structure being 510′ long and about 25′ high. Concrete slabs, 8′ x 8′, 4″ thick, covered upstream side of dam and extended across spillway at west end. Excessive drought in '34 caused earth to settle under spillway slabs and flood waters in Jan. '35 undermined them. City repaired it as emergency measure and then successfully sued contractor and the surety for damages claimed as $10,000. This amount was reduced by court to $2500 with interest and court costs, and court allowed contractor credit of $938 for reinforcement placed in spillway curtain walls in excess of specifications (*City of Osceola* v. *Gjellefald Const. Co.* 279 N W Rep. page 590: Supreme Ct. Iowa, Apr. 10, '38). City Council retained right to give its final acceptance of completed dam and city engineer's final acceptance of construction of dam, under his supervision, did not prevent city from securing judgement. Contractor had agreed to furnish water-tight structure and defect in spillway was attributed by court to undiscovered defects in workmanship. This gave effect to state statute requiring 1 yr. to elapse before contractor and his surety are released from claims for damages.—*R. E. Thompson.*

Walter S. Rae Wins Tunnel Suit. ANON. Eng. News-Rec. **120:** 827 (Jun. 16, '38). Jury in U. S. District Court at Philadelphia awarded contractor damages amounting to $61,859 in suit against Reading, Penna., charging misleading borings on Maiden Creek water supply tunnel. Typical cross-sections on plans provided indicated solid rock throughout and there was no provision for ground supports. Contractor found only mud and boulders in 170′ of tunnel excavation completed: in addition, core boxes were numbered consecutively on plan from one portal while holes were numbered from other end. Contract provided for payment per ft. of tunnel completed and engineer refused to allow partial estimate for excavation only. On finding bad ground continued indefinitely, contractor rescinded contract and instituted suit. Jury found that plans and specifications made material misrepresentations as to character of subsoil, falsity of which could not reasonably have been discovered by contractor; that contractor relied on the misrepresentations and was damaged thereby; and that contractor was entitled to an estimate for work done.—*R. E. Thompson.*

PUMPING

Large Pumps of Unprecedented Efficiency. J. M. GAYLORD. Eng. News-Rec. **121:** 673 (Nov. 24, '38). Colorado R. aqueduct pumping system consists of 5 separate plants with lifts ranging from 146′ to 444′ and totaling 1616′, located up to 126 mi. from point of diversion. A 2-yr. investigation of centrifugal pump performance led to selection of 200-sec.-ft. single-stage units. Adoption of this type of pump effected savings in plant construction many times the cost of laboratory studies carried out. Each plant, when completed, will consist of 8 operating units and 1 spare: initial installations consist of 3 units each. All pumps are of single-suction vertical type, direct-connected to 3-phase, 60-cycle, 6900-volt synchronous motors, water-cooled and totally enclosed for recirculation of air. High efficiency is of great importance, saving

of 1% under full load reducing power cost more than $50,000 annually. This was major objective of testing program. Models (8") of pumps contracted for attained efficiencies of 91.5-92.5%. Bonuses will be paid after field tests for efficiencies in excess of 88%. Even with unusually high efficiencies, annual pump operating cost of completed system will be $5,500,000 at present power rates. Initial pumping installation will cost $22,000,000 and total cost will be $33,000,000. Power supplied from Boulder Dam. Delivery of water is safeguarded by large terminal reservoirs to such extent that power interruptions of several days' duration will not materially interfere with proper functioning of project as whole.—*R. E. Thompson.*

Cavitation Characteristics of Centrifugal Pumps Described by Similarity Considerations. G. F. WISLICENUS, R. M. WATSON AND I. J. KARASSIK. Trans. A. S. M. E. **61**: 1: 17 (Jan. '39). Work described had origin at Hydraulic Lab. of the Metr. Water Dist. of Southern California and the Pasadena Lab. of the California Inst. of Tech. Initial problem, concerning the evaluation of cavitation-test results on centrifugal pumps, was to work out a method of coordinating the results obtained at different speeds on same pump. It was solved by applying the Thoma-Moody similarity law for the cavitation performance of hydraulic pumps and turbines. This law essentially states that for changes in speed and proportional changes in the rate of flow through the machine, the absolute suction head above the vapor pressure of the fluid must be changed proportionally to the square of the speed of rotation, or to the first power of the total head of the machine, in order to maintain similarity of the cavitation phenomena in the machine. It can be expressed by means of the Thoma parameter

$$\sigma = \frac{H_{sv}}{H} = \frac{\text{Suction head above vapor pressure of the fluid}}{\text{Total head of the machine}}$$

In other words, the cavitation behavior of a pump or turbine, relative to its normal behavior, will be the same if the Thoma parameter, σ, is held constant while speed and capacity are changed proportionally to each other. The law, as applied to centrifugal pumps, was verified at the Pasadena Lab. with unusual degree of accuracy. The concepts presented in this paper are but extensions of the fundamental ideas which have already been introduced by Thoma and Moody and which, concerning centrifugal pumps, were checked experimentally at Pasadena. Upon suggestion of Professor Moody, the authors also include in their derivations those of the Thoma parameter and of the physical concepts underlying this whole field of investigation, thereby giving a more complete presentation of all questions involved. These test data give opportunity to illustrate how the new factor can serve as a basis for comparing cavitation behaviors of a wide range of pumps, and for building up corresponding cavitation charts in a logically consistent manner. It should be noted that this paper, with all examples and charts, is concerned with specific speed and head limitations which are due only to the danger of cavitation (as defined), and does not deal with the additional restrictions imposed by mechanical and geometric limitations in the design of such ma-

chines. These restrictions will rule out the practical use of certain regions but this has been disregarded in order not to confuse the principal issue of the paper.—*Homer Rupard.*

Efficiency and Cavitation Tests of Centrifugal Pumps. ANON. Canadian Engineer **75**: 22: 6 (Nov. 29, '38). Work described was done in hydraulic testing laboratory of Dominion Engineering Works, Ltd., Montreal. Tests were made with model pumps having impellers 12" to 20" diam., with delivery up to 4500 g.p.m. The relation of specific speed to efficiency for a series of single-stage pumps is shown with optimum efficiencies at from 110 to 150 specific speed. Limitations on the selection of the most efficient specific speed are design and cost factors in the driving apparatus, problems in the mechanical design of the pump and the problem of cavitation, which occurs at various combinations of total head, suction head and specific speed. Cavitation occurs when the absolute pressure at some point in the machine drops below the vapor pressure of water at the operating temperature. Vapor filled cavities pass into higher pressure zones and collapse. Intense local pressures occur in the zone of collapse. The phenonena is accompanied by a crackling noise which may be objectionable and mechanical vibration and unstable operation are frequently present. The capacity and efficiency of the pump is impaired and pitting of the metal surfaces frequently occurs in the zone of cavitation. This zone in a centrifugal pump is most likely to be adjacent to the inlet edges of the impeller blades. Development of the formula for determining the combination of heads ("Sigma") which will produce critical conditions is shown. The tests on model pumps to find the relation of this "Sigma" value to specific speed are shown diagrammatically. The effect of minor changes in pump design on the cavitation characteristics is discussed. This makes it improper to set forth any general relation between "Sigma" values and specific speeds. Each design of pump should be tested to determine the characteristics of that type. Elevation above sea level and temperature also affect these relationships. An example of the complete calculation for a specific problem is given.—*Homer Rupard.*

Material for Turbine Runners, Pump Impellers, etc. MAX VATER. Deut. Wasserwirtschaft **34**: 20 (Jan. '39). Impact-resistance is but one of a number of properties which are essential in material for the above purposes. It must also have adequate mechanical strength, perfect casting properties, resistance to frictional losses, resistance to corrosion, easy machinability, and in almost all cases, satisfactory weldability. In some cases, it must be able to withstand chemical attack; in some cases, sand abrasion; in steam turbines, its behavior at high temperatures is important. Many methods have been developed within past 10 years for measurement of impact resistance, the principle in all being determination either of degree of penetration, or, what is essentially the same, of the loss in weight in a given time under exposure to given conditions. In the Voith research laboratories, it has been found that by an application of the threshold principle our knowledge regarding this property has been much extended. It has been found that for each material there is a certain definite "v_d", that is, a maximum velocity of water

impact which it can withstand for an indefinite period without being affected. It has been found that v_d-values depend upon chemical composition, while friction loss depends rather upon micro-structure. This knowledge has elucidated some of the remarkable properties of the rustless steels and certain puzzling anomalies. The materials under survey fall into three groups, namely iron alloys, copper alloys, and the light metals. Chromium-nickel alloys, stellite, glass, enamel, earthenware, bakelite, rubber, etc. have been excluded. Of the iron group, cast iron and cast steel were in use just after the war, but with increasing r.p.m. the advantages of adding small proportions of other metals very quickly became apparent. Especially was this true of nickel in the range of 1% to 5%. Comparatively recently the remarkably high water-impact resistance of the high (13%) chromium alloys has brought them prominently to the front. Even very high (30%) chromium alloys are in use for certain purposes. Chromium-nickel steels and chromium-manganese steels and others are being systematically investigated. A number of surface treatment processes in use in the Voith works by means of which resistance, either frictional, or water-impact, may be greatly increased are described. As a measure of the advance which is in progress stands the fact that whereas cast iron and steel begin to be attacked by water impact at velocities (v_d) of 20 to 25 meters per second, the 13% chromium alloys remain quite unaffected below the range of 40 to 50 meters per second. Frictional resistance has also been increased, but not in the same proportion. At the present time there is under investigation in the Voith laboratories a material with a v_d of 60 meters per second and with high frictional resistance also. Of the copper alloy group, ordinary cast bronze and certain special brasses and bronzes are valued for their excellent casting properties and ready machinability, especially for Francis turbine runners, pump impellers, and even for Pelton wheel buckets in special cases. Where cavitation attack is not to be apprehended and mechanical strength approximating that of cast iron is adequate, ordinary cast bronze is suitable. For more exacting requirements, special brasses or bronzes with greatly increased v_d-values must be used. Monel metal is too expensive. For steam turbines, K-Monel metal, rolled α-brasses, special brasses, and special bronzes are in use. Further experiments on this group of alloys are in progress. The light metal group (aluminum and magnesium alloys) have low resistance to water impact and are only suited for enclosed oil systems in which cavitation is less to be apprehended and may often be suppressed by superimposed pressure.—*Frank Hannan.*

Corrosion Due to Cavitation and Drop Impact. HANS MUELLER. Stahl u. Eisen (Ger.) **58:** 881 ('38). Cavitation in ship propeller screws, water turbines and pumps, as well as drop impact in steam and free jet turbines, are discussed and similarity of phenomena is brought out. Destruction of material by cavitation and drop impact depends largely on water velocity, which must reach certain boundary value. Attack progresses from sharp notches and its beginning depends on smoothness and hardness of surface. However, no definite relationship has been found between the severity of attack and the hardness and structure. A Wohler fatigue curve can be set up for repeated stressing by means of a liquid; the water velocity is substituted for the magni-

tude of stress as in ordinary mech. testing. Stresses set up by drop impact are analyzed in attempt to explain type of cavitation caused thereby in flat, hard surface. 23 references.—*C. A.*

Descaling Steam Turbines. JOHN B. ENTRIKIN. Ind. Eng. Chem. **30:** 1279 (Nov. '38). Hydrochloric acid inhibited, as for oil well use, with less than 1% of "certain organic chemicals" was successfully used for reconditioning 2 multistage steam turbines badly scaled from several years of haphazard operation in oil field pumping. Experiments on a similar rotor previously abandoned showed that all concns. of the inhibited acid were without effect on the metal, even at elevated temperatures. Acid was then pumped into the first turbine with enough steam to keep rotor turning at about half speed, 10 gal. of acid being used at rate of 2 gal. per hr. Every 15 min. heads of very wet steam were sent thru turbine to dislodge loosened scale. This treatment dissolved about $\frac{1}{3}$ of scale, softened remainder and removed all rust. Second turbine was similarly treated with 50 gal. of acid in 8 hrs. steaming. Water under high pressure failed to dislodge softened scale, which was then sand-blasted off with 40-mesh hard sand under 125 lbs. per sq. in. pressure, about 3 hrs. being required for each turbine. The inhibited acid caused no appreciable corrosion and sandblasting caused no erosion. After treatment the turbines delivered full rated capacity instead of 50% as previously. With proper boiler water treatment and good operation, the reconditioned turbines were found practically scale free after more than a year's operation.—*Selma Gottlieb.*

Managed Operation Cuts Pumping Station Costs. LOUIS H. MOEHR. Am. City **53:** 11: 61 (Nov. '38). Revision of operating practices at the drainage pumping station of Wayne County, Wyandotte, Mich., was reflected in reduction of power costs from $9.84 per mil. gal. in '31 to $3 per mil. gal. in '37. A system of keeping records, the use of recording charts and their study, and a thorough investigation of plant operation revealed that the storage capacity of the sewers could be used to permit a leveling-off of peak loads. Managed operation of the pumps so as to keep the water under control at all times brought about manual pump control in place of the former automatic control which was responsive to floats. Synchronous motors were used to obtain power factor credits.—*Arthur P. Miller.*

Vertical, Turbine Type Fire Pumps for Grain Elevators. ANON. Ry. Age **106:** 114 (Jan. '39). When the Chicago, Rock Island & Pacific R. R. recently electrified all machinery and equipment at its S. Chicago grain elevators, it also replaced the steam fire pumping equipment with new vertical, turbine type submerged fire pumps which were approved by the Underwriters Laboratory after stringent tests as this is the first installation of this type to secure such approval. One of the fire pumps is a 5-stage, 14" pump rated at 1,000 g.p.m. against head of 125 lbs.; other is a 4-stage, 16" pump rated at 1,500 g.p.m. against same head. There is also a small pressure pump, 7-stage, 6" rated at 35 g.p.m., which operates automatically as does the 1,000 g.p.m. pump, to maintain pressure on the system. The 1,500 g.p.m. pump is manually

controlled. The new pumps were placed below the low water level in the old concrete sump pit and are continually primed. The motors are above the high water level and housed in a 12′ x 14′ sheet metal building. Considered that this installation is superior to the conventional type of horizontal electrically operated pump for this particular location not only through saving in first cost by eliminating priming devices and less floor space but also in operation and heating.—*R. C. Bardwell.*

Speed Control of Electrically Driven Pumps. P. H. GODDARD. Contract Jour. (Br.) Supplement p. 35 (May 11, '38). Water pumping problems, particularly deep well pumping introduces problems in the speed control of electric motor driven pumps. The universal availability of alternating current and the expense of converter plants eliminates use of direct current to produce variable speed operation. The slip ring motor has a very limited application because of its inherent inefficiency. The Schrage motor is a self contained variable speed motor. Approximately 100,000 hp. of these motors have been manufactured in past 20 yrs. It is suitable for voltages up to 600, has infinite speed variation and positive control over any range and maintains high efficiency over a wide range of speed and load. The speed, once adjusted remains practically constant over a wide range of load. A 15 to 1 range of speed can be obtained. Speed can be remotely controlled. The power factor is relatively high over a considerable portion of the speed range. This style of motor is limited to 450 hp. and 850 r.p.m. The Scherbius system control is used for large motors where a speed variation of 20 to 25% is sufficient. Wiring diagrams are given. With this system the motor can use high voltages. Speed regulation is obtained by means of an auxilary regulating machine, usually driven by its separate motor, although it can be driven from the shaft of the main motor. The auxilary regulating machine is an a.c. commutator unit, which varies the speed of the main motor when the excitation of the Scherbius machine is varied. Number of speed steps is regulated by the number of taps on an auto-transformer and remote control may be used. Power factor may be controlled to lead or lag. [Pictures of 550/325 hp, 590/490 r.p.m., 3300 volt units driving circulating water pumps for a power station show the auxiliary equipment to occupy 50% of the floor space required by the main units.] The control equipment may be designed for double speed variation range by the insertion of frequency changer coupled to the main motor shaft. A 2 to 1 speed range can be obtained by this means. Variations of the control schemes may be had for special applications. Author lists 5 units that have been built recently for driving pumps. The speed control equipment may be applied to motors of any size.—*Homer Rupard.*

Maintaining Water Standpipe Level and Pressure Without An Attendant. ERNEST OKE. Eng. Cont. Rec. **51**: 48: 9 (Nov. 30, '38). System employed in Palmerston, Ont., which will automatically control pressure to 1± lb., is described and illustrated. Pressure switch used is of simple, inexpensive type found in private water systems, costing less than $10 and having min. pressure differential of about 10 lbs. To compensate for latter, a bypass with 2 valves (1 and 2) in it is constructed around the check valve in the pump discharge

line leading to the distribution system and standpipe, and the pressure switch is connected to a point between the 2 valves through a line of small-size piping in which a surge tank is incorporated to prevent sudden changes in pressure reaching the switch. With the pump (deep well unit) in operation, pressure at (*a*) main side of valves 1 and 2, (*b*) pump side of valves 1 and 2 and at (*c*) between valves 1 and 2, where pressure switch is connected, will be equal, e.g., say 60 lbs. per sq. in. When pressure in system rises above 60 lbs., pressure switch opens and shuts down pump. Pressure will then be about 60 lbs. at *a* and zero at *b*, while pressure at *c* will drop at rate depending on setting of valves 1 and 2. Assuming a setting of pressure switch for differential of 20 lbs., valves 1 and 2 are adjusted to give pressure of 39 lbs. at *c* when pressure at *a* has dropped to 59 lbs., at which point pump again goes into operation. Thus pressure in supply system is maintained between 59 and 60 lbs., while a differential of 20 lbs. is employed to actuate pressure switch.—*R. E. Thompson.*

HYDRAULICS

Methods Employed to Remedy Water Hammer Shock in Pumping Systems. E. Bruce Hall. Trans. A. S. M. E. **61**: 1: 5 (Jan. '39). Describes certain typical problems which have been encountered in English practice in pumping station installations, where surge conditions have been remedied, and the changes made to remedy them. The cases were analyzed by pressure recorder charts. Three cases described in detail, (1) a hydraulic elevator installation with accumulators, (2) a pumping system with an air tank and, (3) a distribution system booster station pumping into an elevated tank. First two cases solved by replacing ordinary flap check valves with "recoil valves" which worked slowly and softly. In third case gate valve control was desirable so a valve with a shape of port designed to give proper relation between stem movement and port area was used. The ideal check valve would reach its point of complete closure at the instant that the motion of water in the discharge line became zero. Some cases cannot be solved by proper check valves, but require air chambers. Introduction of an air chamber changes hydraulics of the line and necessitates a properly designed check valve. The conventional type of check valve can be improved to make it a highly responsive piece of apparatus suitable for dealing with mobile water columns.—*Homer Rupard.*

Calculation of Water Hammer Caused by the Shutdown of Centrifugal Pumps. W. L. Boerendans. Gas-u. Wasser. **81**: 690, 710 (Sep. 24, Oct. 1, '38). The ordinary formulas for calculation of water hammer are given and it is shown how the effect of the slowdown of the pump on the flow of water after switching off the current can be calculated. A method for use of a steam indicator for measurement of water hammer pressure changes is described. The calculation of these pressure changes is given, mainly based on Bergeron graphical solution. Theory was tested on two pipe lines, one 5 mi. long of 36" diam., and one about 1.4 mi. of 12". Found that presence of air in the pipe line reduces pressure as well as velocity of the pressure wave, even very small amounts of air reduce this velocity considerably. When flow is not completely

shut off, the calculation can only be made if friction can be neglected. Presence of incrustation, causing friction, reduces the velocity of the pressure wave. Difficulties in checking the results were also due to the inertia of certain measuring apparatus, especially the Venturi meter. If all pump characteristics, pipe conditions, and hydraulic limits are known the pressure variations can be calculated to agree fairly well with measured values.—*Max Suter.*

Water Hammer. S. LOGAN KERR. W. W. Eng. **91:** 1238 (Sep. 14, '38). No one rule can be given or single formula set up to give surge intensity of water hammer. Elastic wave theory with corroborative tests has allowed correct solution of many problems; water column not a rigid mass and pipe walls do stretch under increased pressure, contract when pressure reduced and vibrate in common with all elastic bodies according to certain known laws. Velocity of surge wave, a, can be computed with high degree of accuracy if diam., thickness and material of pipe walls known. Important to detn. critical time of pipe, i.e. time for one round trip of pressure wave from valve to reservoir and return, ($2\ L/a$) establishes limit of accuracy of most of approx. water hammer formulas in use. In simple pipe line of uniform construction throughout and free from branches, max. possible surge will occur when flow is cut off uniformly in a time just equal to the critical time, if cut off at any faster rate pressure goes up more quickly, but not any higher. If closure takes place instantaneously, pressure will rise abruptly to max. and stay there for $2\ L/a$ sec. Max. surge dependent only on velocity of surge wave and velocity of flow and for any closure in $2\ L/a$ sec. or less, its intensity will be $h = a\ V/g$; where h is excess pressure rise or surge head, a surge wave velocity, and V velocity of flow in pipe. If branches or dead ends on line, max. surge may be 2 or 3 times value computed from formula. In such cases involved application of theory needed; with pipe lines several mi. or more in length with 1 or more branches, design should include higher degree of safety than usual. Surges of less than max., dependent on same basic factors as max.,—length, diam., thickness and material of pipe. Graph given for use as approx. means of finding surge velocity in steel, c.i. and cement asbestos pipe; basic formula too cumbersome to use. If valve closure made in longer than critical time, intermediate setting of valve and flow at critical time determine hammer. In operation of ordinary control valves, time of operation is principal factor to consider; time to cut off flow should be such to keep surge within 10% to 20% above normal. In automatic valves, usually less surge if valve closes too slowly rather than if too rapidly. In general control valves should be closed in minutes rather than in seconds. In water hammer investigations, exceptions to general rule often point way to proper solution.—*Martin E. Flentje.*

Speed of Water-Hammer Pressure Wave in Transite Pipe. LEWIS H. KESSLER. Trans. A. S. M. E. **61:** 1: 11 (Jan. '39). Shows the determination of the speed of travel of the pressure wave due to valve closure in a class 150, 14″ cement asbestos pipe 34,237′ long. Shortly after line was placed in service water hammer pressures presumably caused several joints to leak. Pressure-time diagrams were made on the line while in regular service. Laboratory

tests made on some 4" Transite pipe. Compression, tension and bending tests were made on a section of 14" Transite pipe. These laboratory tests showed a modulus of elasticity of 3,400,000 for class 150 Transite pipe. This corresponded to the speed of 3,340′ per min. found for the pressure wave speed in the 34,237′ pipe line. Author recommends use of this value for the modulus of elasticity until further information is available.—*Homer Rupard.*

A General Hydraulic Flow Formula. T. Blench. Wtr. and Wtr. Eng. (Br.) **40:** 292 (Jun. '38). Formulas for uniform turbulent flow fall into three groups: (1) for smooth, rigid boundary, (2) for rough, rigid boundary, and (3) for "incoherent" boundary. An incoherent boundary is formed in a channel which picks up and lays down its own material. For the first condition formulas of the type $V = KR^pS^q$ are well known. The only serious rival to exponential formulas is that of Prandtl's in the form

$$V = \sqrt{8gRS}\left(2.0 \log_{10} \frac{2R}{l} + 1.74\right)$$

The writer believes that there must be one general formula of the form

$$V = \phi\ (R'x)\ \sqrt{gRS}$$

in which ϕ is an abstract constant, and the value of x is δ for smooth boundary, l for rough boundary, and t for incoherent boundary conditions. δ is the boundary layer thickness, l is the protuberance height of roughness on the boundary, and t is silt diameter, with some modifications. A comparison of formulas shows Manning's to be a good approximation of dynamic correctness. —*H. E. Babbitt.*

Use of Small Scale Model to Calibrate Overflow Dam. Raymond Boucher. Rev. trimestr. can. **24:** 411 (Dec. '38). The dam, which is on the Rivière du Lièvre at the Rapide des Cèdres, is shown in transverse section. It is nearly 27′ high above river bed and has a 10′ wide flat crest with ogee downstream face. Piers divide the spillway into four parts each 24′ long, and each controlled by a Stoney sluice-gate. The scale of the model was one-fiftieth of the prototype. It was made at the hydraulic laboratory of the Montreal École Polytechnique. Maximum head assumed possible on the prototype is 20′: model was searchingly tested in the corresponding range, both when free overflow was permitted and under sluice-gate control. The formula

$$Q = CL\left(H - \frac{V_o^2}{2g}\right)$$

was used for calculating discharge, in which:

Q = quantity discharged in c.f.s.,
L = length of crest in feet,
H = head of water in feet, reckoned from crest level.
V_o = mean velocity of approach, in feet per second,
C = the coefficient of discharge, and
g has its usual significance.

According to Froude's law of similitude, the coefficient, C should be the same for the prototype as for the model, and Q_p, the discharge on the prototype, should be obtainable from Q_m, the discharge on the model, by the simple relationship $Q_p = Q_m \times \lambda^{\frac{5}{2}}$, where λ is the linear ratio of prototype to model (in the present instance, 50). Found in practice that C obtained from the model is rather too small, and that the difference is greater the smaller the model. In the first series of 10 exp'ts at heads (prototype) from 20′ down, made for comparative purposes before the gate piers had been added, C ranged from 2.790 to 3.683, the relationship, when plotted against head, being approx. linear. In second series of 11 exp'ts, after piers had been added, but with all four gates fully open, increase in C was from 2.784 to 3.683, relationship with head being again approx. linear. In the third series of 11 exp'ts the two center gates were fully open and the two side gates fully closed. C increased from 2.804 to 3.384, again almost linearly with head. In the fourth series of 10 exp'ts only one center gate was open: C increased from 2.761 to 3.321, its course when plotted against head being somewhat less regular than in the three preceding series, but still not far from linear. Remaining 94 exp'ts were studies of discharge through a single gate only partly open, the (prototype) heights of opening chosen being 1′, 2′, 4′, 6′, 8′, 10′, 12′, 14′, and 16′; heads, as before, from 20′ down. Discharge plotted against head for each gate height. In every case a sharp break in the curve appears at the point where discharge changes its characteristics from overflow conditions to orifice conditions; which is but natural. It is now hoped that a careful series of measurements will be undertaken on the prototype itself in order to establish the dependability of the model as a means of calibration.—*Frank Hannan.*

Dual Parshall Flumes Measure Wide Range of Flows. H. S. RIESBOL. Civ. Eng. **9**: 17 (Jan. '39). Parshall measuring flumes have been adapted to measurement of a wide range of flows in making hydrological studies near Coshocton, Ohio. Combined large and small flumes have been designed to handle flows between 80 and 1,000 c.f.s. An outstanding advantage of the Parshall flume for the purpose indicated is the small effect on the rating curve resulting from wide variations in velocity of approach. A composite rating curve for the 15′ flume, with its 1′ supplemental flume is given.—*H. E. Babbitt.*

Measurement of Debris Laden Stream Flow with Critical-Depth Flumes. (*Discussion of previous paper.*) Proc. A. S. C. E. **64**: 560 (Mar. '38). EDWIN S. FULLER. Various types of rating flumes form excellent controlling sections for gages located a short distance upstream from the entrance to the rating flume. The rating curve for a gate (gage?) situated a short distance upstream from the "control" section will have the form

$$Q = K\, b\, H^u \qquad (11)$$

in which u is an exponent equal to 1.5; Q is the discharge in c.f.s.; b is the breadth of the rectangular "control" section, in ft.; H is the height of the water surface in ft. above the lip of the controlling section; and K is a constant depending only on longitudinal channel conditions. If rating curve for

rectangular flume of uniform cross-section and slope is computed by the Manning formula, it will be found to be fitted closely by the formula

$$Q = K_1\, b\, H^{1.5} \qquad (12)$$

which, except for the coefficient, is the same as equation (11). Velocity of approach has a marked effect on entrance losses and on rate of acceleration in the rating flume at the stilling well connection. Establishment of a debris dune at the entrance to the rating flume would tend to cause a change in entrance velocity similar to that caused by narrowing the approach channel, and a corresponding increase in rating-flume discharge coefficient would be expected. Most stable natural controls for a gage on a debris-laden stream are those in which, at all stages, there is very slight increase in water-surface slope in a short distance downstream from the gage. At such gaging stations there is a very definite relation between the exponent in the rating curve formula and the shape of the cross section of the stream at the point where the change in slope of the water surface occurs. *Ibid.* **64:** 818 (Apr. '38). Harold K. Palmer and Fred D. Bowlus. Debris-laden streams may be divided into three classes: (1) muddy water in which the debris consists of fine silt, ordinarily considered as that passing a 200-mesh sieve, distributed uniformly throughout entire cross-section, (2) water carrying suspended load of coarser, sandy material, the bulk of which is carried along in the lower part of the stream, (3) water transporting rocks which roll and slip along the bed. Any clear-water measuring device will give satisfactory measurement of the class one stream. All attempts in the past to make use of critical-depth measurements have failed because of the difficulty of locating the point of critical depth. Whatever form the throat and transition may take, the method requires a point of critical velocity which, in turn is dependent upon a change from mild to steep flow. If no measurements are made above the throat it would seem that the channel should be only wide enough to insure critical velocity in the throat at all flows. Harry F. Blaney. The application of flumes to measurements in mountain canyons involves problems not ordinarily encountered in valley areas. A large flume, for example, placed directly in a stream channel where the grade is as steep as 10% may have a rating curve quite different from the standard calibration. There are denuded watersheds in Southern California where no type of flume will measure the debris-laden stream flow accurately.—*H. E. Babbitt.*

The Force Required to Move Particles on a Stream Bed. William W. Rubey. U. S. Geol. Survey. Prof. Paper, 189-E. The so-called "sixth-power law," announced more than a century ago, states that the weight or volume of the largest particle that can be moved by a stream varies as the sixth power of the stream *bed velocity*. The latter is almost impossible to measure accurately. An alternative law states that the size of the largest particles moved by a stream varies as the depth of water times slope of stream. A third theory states that the dislodgment of particles from a stream bed depends on the lift induced by the velocity gradient or the rate of shear between fluid filaments. The predicted results of the three theories are in rough, qualitative agreement. Experiments show that the force necessary to start particle movement depends

on the mean velocity of a stream and on the depth-slope product. The velocity in the immediate vicinity of the particle on the stream bed is more significant than the mean velocity of the entire stream. An estimate of the "bed" velocity can be based on the coefficient of channel roughness or the size of the particles making up the "sixth-power law" but the smaller particles require much higher velocities than are indicated by this law. Departures from the sixth-power law for smaller particles become large enough to be significant when the laminar film is thicker than the radius of the particle, thus indicating that frictional drag or "hydraulic lift" rather than impact is the force that starts a movement of small particles. Equations based on laboratory data give reasonable estimates of the maximum size of pebbles moved by some large natural streams but much information is required about a stream in order to make the necessary calculations. It is to be noted that the sixth-power law measures only the size of larger particles moved and has nothing to do with total load or amounts of debris transported.—*H. E. Babbitt.*

Du Buat's Experiments. F. W. Woods. The Engr. (Br.) **165:** 386 (Apr. 8, '38). Du Buat (1786) was one of the earliest research workers who discussed the soil-erosive potential of streams of water. He measured the maximum surface velocity by means of surface floats in midstream and sought to ascertain the bottom velocity or the velocity of the water at stream bed level by means of balls, made of wax, sawdust, and cement, having a sp.gr. of 1.08. Solids of sp.gr. greater than water need velocities proportionate to their magnitude, and inversely proportionate to the stream depth, to move them . . . "the resistance of the channel surface to flow is not affected differentially by differences in the rugosity of different solid materials." The hydraulic measurements which led Du Buat to this mistaken conclusion must have been erroneous and, therefore, his conclusions as to "bottom velocity," mean velocity, and "velocity close to bed" must also have been mistaken. The erosive potential of a filament of water in a current depends on its proximity to the erodible solid surface of the channel as well as on its velocity. The largest, coarsest particles of detritus are found in the lowest depths of the stream, where the velocity is the least but friction turbulence greatest. Dupuit expressed the opinion in 1848 that the power of suspension in flowing water of solids heavier than water is proportionate to the difference of velocity filaments of the current at uniform distances apart in a vertical plane. Cunningham, Von Wagener, Lamb, Gilbert, etc. have pointed out during the past 60 yrs. that the "bottom velocity" is probably zero, and although this, if true, is sufficient to knock the bottom out of the conception of erosion being due to absolute velocity, of finite magnitude, the text books are generally silent on the point.—*H. E. Babbitt.*

Tidal Datum Planes and their Use in Engineering. Elliott B. Roberts. Boston Soc. Civ. Eng. **25:** 308 (Apr. '38). Much economic loss has resulted from use in surveys of impermanent datum planes. Search for rational datum plane has led inevitably to use of ocean water surface and to establishment of mean sea level datum. This datum is mean elevation of water surface considering all stages of the tide. Because of fluctuations in water levels, 19

yrs. of observations required to balance all significant components, 9 yrs. acceptable for practical use and a secondary determination may be had from 4 yrs. or less of observation. Discussion of characteristics in connection with conformation of tidal datum planes to level surfaces given.—*Martin E. Flentje.*

Velocity Profiles and Flow of Fluids Through a Contracted Pipe Line. F. V. A. E. ENGEL AND A. J. DAVIES. The Engr. (Br.) **146:** 720 (Dec. 30, '38). Contractions considered are an orifice plate and a nozzle inserted in a pipe line. On the basis of investigations of Prandtl, von Karman, and Nikurdase combined with use of Reynolds number, it is now possible to predict the distribution of velocity in a cross section of a stream if the frictional coefficient of the walls is known. In case of flow through contracted pipes velocity distribution is important, but for better understanding the pressure distribution in front of a contraction must be dealt with. For example, in front of an orifice plate there is a slight gradient due to frictional losses followed by a comparatively steep increase in pressure close to the upper face of the plate. It is known that the application of Bernoulli's theorem to the flow equations for orifices and nozzles is subject to limitations. The correction depends on the distribution of local velocities. Two mathematical investigations of velocity distribution were made together with a few experimental verifications.—*H. E. Babbitt.*

Entrainment of Air in Swiftly Moving Water. E. W. LANE. Civ. Eng. **9:** 89 (Feb. '39). The whiteness of the water is a rough indication of the amount of air entrained in it. Whiteness in the sheet of water falling over a spillway is due to turbulence resulting from: (1) currents set up at the dam crest, (2) roughness of the dam surface, (3) thickness of the overflowing sheet, and (4) height of the dam. Whiteness of water moving rapidly in chutes is due to the same conditions and, in addition, to the conditions at the sides. In design of overfall spillways and steep chutes the slowing down of velocity due to entrainment of air and the increase in the volume of fluid to be carried are important factors. There is no fixed velocity at which air entrainment commences and the belief that there is a maximum velocity of about 80′ per sec. of water flowing down a steep channel does not seem to have much justification.—*H. E. Babbitt.*

Hydraulic Jump in Trapezoidal Channels. C. J. POSEY AND P. S. HSING. Eng. News-Rec. **121:** 797 (Dec. 22, '38). Practically all previous observations were made in rectangular channels. Tests (200) described were run in trapezoidal channels with side slopes of 1:2, 1:1 and 2:1 and bottom widths of 1.250′, 0.551′ and 0.235′, respectively. In appearance, jump in trapezoidal channels differs from that in rectangular channels in that wedge-shaped wings form on each side. Length of jump is less definite in former than in latter, and for flat side slopes is considerably greater. Nearly all lengths measured fall within extremes given by formulas:

$$\frac{L}{d_2} = 5\left[1 + 3\left(\frac{W_2 - W_1}{W_1}\right)^{0.7}\right] \quad \text{or} \quad \frac{L}{d_2} = 5\left[1 + 6\left(\frac{W_2 - W_1}{W_1}\right)^{0.3}\right]$$

where L is length of jump measured along centerline of channel, d_2 is depth after jump, and W_1 and W_2 are widths of water surface before and after jump, respectively. Best average values were given by formula:

$$\frac{L}{d_2} = 5\left(1 + 4\sqrt{\frac{W_2 - W_1}{W_1}}\right).$$

These formulas should provide necessary information for preliminary design and selection of economic side slope but large-scale tests would be advisable before construction of any important work is undertaken.—*R. E. Thompson.*

Hydraulic Jump in Enclosed Conduits. E. W. LANE AND C. E. KINDSVATER. Eng. News-Rec. **121:** 815 (Dec. 29, '38). Study conducted at Univ. of Iowa to determine reliability of commonly used theory of hydraulic jump when applied to enclosed conduits. Experiments were made in 6" transparent celluloid pipe, high velocity and partial depth of flow necessary to form hydraulic jump being produced by introducing constrictions in pipe which produced stream of water along bottom of pipe with supercritical velocity and level upper surface. In all, 35 different conditions were studied. In general, results indicated that commonly accepted momentum theory of hydraulic jump can be applied to channels of irregular shape and to hydraulic jump which takes place in an enclosed conduit.—*R. E. Thompson.*

Fifth Annual Report of Special Committee on Hydraulic Research. Civ. Eng. **9:** 109 (Feb. '39). Progress is reported in seven research projects: (Project 67a) "Conversion of Kinetic to Potential Energy in Expanding Conduits." Attempts being made to measure quantitatively the turbulence intensity at various points throughout an expanding conduit, measurement being made by observations on different frames of a moving picture film. (Project 67b) "Travelling Waves on Steep Slopes." Studies of travelling waves have been made by means of photographs of flow in steel channels of adjustable slopes with rectangular and with trapezoidal cross sections. (Project 67c) "Phenomena of Intersecting Streams." Work has been done at the intersection of both open channels and of closed channels but at present work at the former has been suspended because of the multiplicity of variables to be considered. (Project 67d) "Curves in Open Channels." Velocity measurements are being made in a 180° bend of a rectangular section 18" wide and of varying depths up to 10". The measurements being made with aid of a motion picture camera and globules of a mixture of xylol, n. Butyl Phithalate, and a dye. (Project 67e) "Sedimentation at the Confluence of Rivers." Data collected in the performance of these experiments may be classified in following groupings: (1) study of tractive force and equilibrium slopes for various rates of sand transportation, (2) contour records at the confluence for each series of observations, (3) mechanical analyses of bed sediment, and (4) records of current patterns at the confluence. (Project 67f and g) "Air Resistance to Flow of Water in Open Channels" and "Simultaneous Flow of Liquids and Gases in Pipes." This is an attack on the problem of flow of water in steep open and closed channels together with its associated phenomena of entrained air.—*H. E. Babbitt.*

New Hydraulic Laboratory at St. Anthony Falls. Anon. Eng. News-Rec. **121:** 725 (Dec. 8, '38). Brief description of new hydraulic laboratory for University of Minn. located on Hennepin Island at St. Anthony Falls in Mississippi R., utilizing early water rights and site of abandoned Minneapolis water pumping station. Facilities provided include main experimental laboratory, hydraulic machinery laboratory, turbine-testing laboratory, large-scale volumetric measuring tanks and administration and lecture rooms. —*R. E. Thompson.*

Hydraulic Laboratory of the Federal Institute of Technology, Zurich. Engineering (Br.) **146:** 3 (Jul. 1, '38) and **146:** 149 (Aug. 5, '38). Building consists of two wings, each three stories, connected by a central, single-story section. Length of building is 230′. Center part of the structure occupied by main laboratory in which large models of river beds, flumes, or other hydraulic works may be constructed. Basement of this part and of the wings occupied by experimental water channels. In both wings there are laboratories for carrying out tests on turbines and pumps. Large water storage tank is provided from which the various supplies are drawn. Experimental work requiring employment of high-pressure water can be carried out in laboratories in both wings.—*H. E. Babbitt.*

STREAM POLLUTION

Four State Agreement on Delaware River Pollution. Anon. Pub. Wks. **69:** 12: 9 (Dec. '38). Health Depts. of N. Y., N. J., Pa., and Del. have ratified agreement to control pollution of Del. River. Each state agrees to enact and enforce adequate legislation to keep river and tributaries in clean and sanitary conditions provided for in agreement. River basin over 12,000 sq. mi. in area on which live approx. 5 mil. people. N. Y. and N. J. are preparing to use much water from basin for water supplies. Zoning and detailed limits of pollution for each zone given in article.—*Martin E. Flentje.*

Mitigation of Trade Waste Pollution in West Virginia. L. Kermit Herndon and James R. Withrow. Trans. Am. Inst. Chem. Engrs. **34:** 327 ('38). After establishment of the State Water Commission of W. Va., detailed surveys were made of various watersheds of the state to show nature, extent and effects of existing pollution. These surveys formed basis for logical detn. of remedial work necessary to protect major uses of the stream and served also as reference to measure efficiency of measures adopted. A state-wide summary of sewage conditions indicated that population of 500,000 was contributing sewage wastes to the streams. At several points sewage-treatment plants were necessary. Largest problem is from acid drainage from bituminous coal mines, drainage from 13 coal seams giving 2,874,000 lb. of acid per day. A mine-sealing program is now reducing this pollution load. Coöperative work with industries has resulted in installation of effective tannery waste-disposal systems, phenol-recovery units at by-product coke ovens, and material reduction of wastes also from paper mills, oil refineries and chem. plants.—*C. A.*

The Pollution and Natural Purification of Illinois River Below Peoria. W. H. WISELY AND C. W. KLASSEN. Sewage Works J. **10:** 569 ('38). The Illinois River between Peoria and Beardstown was studied during the critical months of July and Aug., '36. From the D. O. and B. O. D. detns., oxygen balances, effects of sludge deposits, deoxygenation and reaeration coeffs. are detd. From these, the limits of allowable industrial pollution are calcd. Forecasts of conditions and allowable pollution in '40 are made, based on reduced diversion of Lake Michigan water in '40 by Chicago Sanitary District, channelizing of the river and construction of a dam below Pekin. Calcns. indicate a reduction in the oxygen resources of the river in '40 because of the reduced flow and a localizing of critical conditions immediately below Peoria and Pekin because of the dam.—*C. A.* Article also contains excellent material applicable to stream pollution surveys in general.—*P. H. E. A.*

Fourth Report of the Joint Advisory Committee on River Pollution to the Minister of Health and the Minister of Agriculture and Fisheries of Great Britain. H. M. Stationery Office, London, '37. 17 pp. Report was prepared in accordance with request made in '35 by the two Ministers that the Committee consider "the position with regard to river pollution which had developed in consequence of the passing and operation of the Land Drainage Act, '30, and in particular whether measures could be devised for dealing with the prevention of pollution of rivers without the appointment of entirely new bodies for that purpose." Committee states "There has been growing recognition . . . , that there is need for the administration of the river pollution prevention law to be in the hands of suitable bodies with jurisdiction over the whole river, or at least the non-tidal part of the river. . . . There is a large and growing body of opinion amongst those concerned with rivers that notwithstanding the advantages which would arise from a single pollution prevention authority for the whole of a river in place of the present multiplicity of authorities, the setting up of separate bodies for this particular purpose would be contrary to the best interests. . . . The view which has been advanced to us, and with which we entirely concur, is that the time has arrived for seriously considering not only the reduction of the number of bodies dealing with river pollution by the concentration of that function in one body for the river, but also the concentration of functions in relation to a river into one body for the whole of the river. At the present time, while there is a multiplicity of authorities with river pollution prevention powers in a river there are also numerous other river functions (for example, drainage, fisheries and navigation), sometimes overlapping and not infrequently conflicting, exercised independently by various bodies. . . . We recommend that the question of the formation of river authorities in whom should be centralized the functions relating to river pollution prevention, land drainage, fisheries, water abstraction and, in suitable cases, navigation, should receive immediate consideration by an authoritative body who would hear evidence and arrive at conclusions. . . . We desire to make it clear that we have not in mind any curtailment of the work which is now being done, but simply a centralization in representative bodies, of powers and duties relating to a river and its tributaries, which we believe may prove the ideal solution of the present difficulties. We feel that

such bodies would not allow any one interest in the river to be developed to the prejudice of any other, but charged as they would be with general responsibility for interests affecting the river, would hold the balance and come to their conclusions in the best interests of all concerned, thus securing a collective administration of the various river functions to the great advantage of the general community."—*P. H. E. A.*

Purification of Swedish Water Courses. C. SCHMIDT. Svensk Papp-Tidn. **40:** 435 ('37); Paper Tr. J. **106:** 38 ('38). Discusses legal and economic problems connected with efforts to reduce the pollution of streams and lakes in Sweden. It is impossible to solve the problems by general legislation. Physical, chemical and biological conditions vary and each case requires individual study and consideration.—*W. P. R.*

CORROSION AND CORROSION CONTROL

Calculation of Chemical Dosages Required for the Prevention of Corrosion. EDWARD W. MOORE. J. N. E. W. W. A. **52:** 311 (Sep. '38). Ca saturated water generally held to be non-corrosive. Because of unreliability of marble test and desirability of eliminating much of the considerable lab. work req'd. in McLaughlin method new method has been developed for computing from Langelier's formula chemical quantities req'd. to give saturation. For pH range 6.5-9.5, Langelier's original formula can be simplified and converted so that conc's. are in p.p.m., in which form:

$$pH_s = K - (\text{log of p.p.m. Ca}) - (\text{log of p.p.m. alk. as } CaCO_3)$$

where pH_s is the pH of saturation, K is a constant dependent on temp. and total salt content of the water. Each p.p.m. hydrated lime increases Ca content 0.54 p.p.m. and alk. 1.35 p.p.m. (as $CaCO_3$); K taken from included table. The values of pH_s so obtained are plotted against varying lime dosage and second curve made of increase in pH with lime as detnd. expt'ly. Intersection of 2 curves gives req'd. lime dose and pH of corrected water. If amt. of Ca and alk. added by any chemical used for pH correction known, dosage can be computed in this manner. When hydrated lime used, dose should not exceed 1.68 times p.p.m. CO_2 and 0.74 $\times$ bicarbonate alk. Methods result in less lab. work, Ca content of water, however, must be known.—*Martin E. Flentje.* (See also J. A. W. W. A. **31:** 51 (Jan. '39) for related discussion by same author.)

Corrosion and the Formation of Protective Coatings by Waters in Distribution Systems. JOHANNES KOOIJMANS. Gas-u. Wasser. **81:** 611, 628 (Aug. 20, 27, '38). Data on many tests of the cause and course of the corrosion are given. Different types of natural waters were used to obtain the conditions existing in practice in approaching chemical equilibrium. It is shown that organic substances slow down the appearance of an equilibrium, and the kind of organic matter is more important than the amount. Calcium carbonate is precipitated by the loss of CO_2 into the air. Organic matter can hinder this precipitation even if some solid calcium carbonate is dispersed in the water. The formation of a protective coating on the pipe is explained without the

use of the theory of adsorption of CO_2 on ferric hydroxide, but by the simultaneous precipitation of HCO_3 ions with the hydroxide. Ferrous hydroxide alone cannot form a protective coating. Iron goes into solution by the effect of hydrogen, which comes either from carbonic acid or from bicarbonates. Calcium bicarbonates so affected will precipitate calcium carbonate. The dissolved iron will form ferrous bicarbonate, which will change under the influence of oxygen and water to ferric hydroxide and carbon dioxide. If there is lack of oxygen, the iron will remain in the ferrous form and more calcium carbonate is precipitated, in extreme cases without formation of a protective coating. A ferro-ferri proportion of 1:3.5 to 1:5 is present in good coatings. The first layer on the metallic iron is pure rust. On this a mixture of lime with iron is deposited. The calcium carbonate forms only a protective coating if deposited slowly in crystalline form. Rapidly precipitated amorphous calcium carbonate does not have enough adhesion to give a protective action. There is about ten times as much iron as calcium in the protective coating. Aggressive water can redissolve this coating. A protective coating free of calcium, but composed of ferrous carbonate and ferric hydroxide can be formed in water low in oxygen but high in CO_2.—*Max Suter.*

Principles of Corrosion and It's Prevention. FRANK N. SPELLER. J. N. E. W. W. A. **52:** 228 (Jun. '38). Corrosion one of major engineering problems; underlying principles comparatively simple but because of many factors involved problems in practice exceedingly intricate. Metals are unstable and tend to revert to compds. that are more stable. 2 types of corrosion: (1) direct chem. attack and (2) electro-chemical action; latter of most importance to water works field. Two pieces of metal in electrolyte cause flow of current from one to other, one going into solution; in corrosion in water iron goes into soln. and hydrogen plates out on cathode. Can be restrained if either anode or cathode polarized by deposit, as when chromates form film on anode, lime on cathode. Much safer to have cathodic protection. Driving force of original corrosion reaction is the solution pressure of metal, affected by film formation, depolarization by oxygen, velocity of water and temp. 3 principles of protection depend on (1) improvement in resistance of metal by alloying with metals that build up protective films, (2) artificially applied coatings, (3) treatment of environment. Cathodic protection of pipe lines coming rapidly into use in oil and gas fields.—*Martin E. Flentje.*

The Corrosion of Metals by Salt Solutions. G. D. BENGOUGH, U. R. EVANS, T. P. HOAR AND F. WORMWELL. Chem. & Industr. **57:** 1043 ('38). Discussion of conclusions arrived at as result of work on corrosion of metals by salt solutions carried out independently at the Chemical Research Lab., Teddington, and in the Metallurgical Labs., Cambridge Univ. Agreed that wet corrosion usually involves an electrochemical mechanism, primary corrosion occurring at anodic areas. If both the anodic and cathodic products are freely soluble, corrosion may proceed rapidly; if the cathodic product is sparingly soluble corrosion may be retarded owing to deposition of the cathodic product, e.g. calcium carbonate, on the cathodic areas; corrosion may be almost stifled if the anodic product is sparingly soluble, e.g. when dilute alkali or sodium

phosphate are present. If, however, there is just insufficient inhibitor to prevent corrosion, intense corrosion will occur in small areas. Rate of corrosion may be increased by presence of oxygen, but when clean metal surfaces are exposed to gaseous oxygen before they are submerged corrosion may be reduced or inhibited. Distribution of corrosion on totally immersed and partially immersed specimens is considered. When samples of zinc, iron or mild steel are totally immersed in stagnant solutions of potassium or sodium chloride corrosion starts at a large number of points, but after a few hours it is confined to several large areas; films are deposited over the other areas. Relative sizes of corroded and protected areas depend on period of action and on nature and concentration of electrolyte. In solutions under atmospheres of oxygen the corrosion products gradually consolidate into hard shells which reduce the rate of corrosion, but in air consolidation does not occur and rate of corrosion remains same for months or even years. When specimens are partially immersed in solutions of sodium and potassium salts there is usually an area immune from corrosion near the water line, and a corroded area a little lower down. Alkali is the cathodic product and it tends to accumulate along the water line where excess oxygen is present; iron salts are deposited in contact with the metal and protect it from further corrosion. After a time corrosion creeps up towards the water line. In solutions of calcium and magnesium salts the whole immersed area becomes slightly corroded with exception of a narrow band along the meniscus, on which is deposited a layer of calcium or magnesium compound. Factors affecting rate of corrosion include movement of the liquid, cross-section of the vessel in which specimen is placed and depth of immersion up to about 15 mm. Size and purity of specimen does not affect rate of corrosion but purity may influence the distribution of attack.—*W. P. R.*

The Action of Tap Water and Soils upon Pipes. R. P. van Royen. Water (Netherlands) **22:** 193 (Sep. 23, '38), 201 (Oct. 7, '38), 210 (Oct. 21, '38). *Pipe material.* Discussion of steel, cast iron, lead, tin, copper, brass, bronze, zinc and their alloys; description of potable water with its salts and gases; discussion of soils in which pipes are buried, containing liquids with dissolved salts and gases. Ordinarily the dissolved salts have no effect on metals, but when oxygen has been depleted by organic matter, anaerobic biological action occurs, resulting in products uniting with the iron. Moisture in the soil moves slowly, resulting in rapid oxygen depletion and corrosion. In pipes where more than one metal is present the difference in potential results in deterioration of weakest metal. The more salts the greater the difference in potential. Corrosion is electro- or biochemical in nature. Steel pipes, protected with zinc, corrode rapidly under high temperature conditions when salt concentrations are relatively high, even when the O_2 and CO_2 have been driven out. These gases accelerate corrosion, so that corrosion will be more severe at places where the gases are trapped (nuts, nipples, bends, etc). Degasification is helpful; warm water reservoirs in the system should have a smooth inner surface, placed on a slope to facilitate escape of gases and built as high as possible. Zinc covered steel has as a rule short life in warm water systems, in addition to producing red water. Warns against using copper or brass in same system with iron pipe. Even use of a few iron nipples caused severe

corrosion. Corrosion may be uniform,—pitting or tubercles. Tubercles are small electro- or biochemical factories where the iron is oxidized. When tubercles are small corrosion process has stopped, when large it is in progress. May be protective. May be protected by bitumen, provided layer is thick enough, uniform, made from proper materials, is properly applied, non-porous, and no hair cracks; otherwise water penetrates beneath and layer is loosened. When hole is formed by corrosion, water passes through rapidly causing erosion. Degree of erosion depends upon metal. Cast iron pipes contain more carbon than steel pipes (about 3.5%). Part of carbon is graphite forming local carbon-poor elements, causing "graphitizing," especially where brass pipes are connected. Pitting is prevalent in c. i. pipes, but more serious is graphitizing in sulfate bearing soil water. Without losing its form the c. i. becomes soft, non-crystalline; can be cut with a pocket knife (biochemical process); case is discussed where resilience or bending power was reduced to 1% of original. Corrosion of c. i. pipe about equal to steel pipes under same conditions, but c. i. is thicker. Normal method of asphalting is insufficient in aggressive soils. Lead pipe is more resistant, corrosion forms protective layer. With initial solubility power of 1 p.p.m., and standing for 16 hrs. in pipes the lead content of water, after a few months age of the pipes, is not more than 0.3 p.p.m. From toxicological standpoint this is important. If solubility power of water remains above 0.3 p.p.m. lead pipes cannot be used or must be lined with tin. Lead is very resistant to soil water. A lead pipe buried 19 centuries was still in good condition. O_2 and CO_2 are most important in lead corrosion; O_2 content of ground water is usually low and pipes are protected by simple aeration. High O_2 content of surface water is mainly responsible, but excessive CO_2 is an important factor. Sufficient lime salts must be present to prevent action of CO_2 and produce deposit on inside of pipes. Surface or ground water left standing in pipes has more lead in solution than with short contact times, therefore length of piping is factor. Normally, one closet discharge should empty entire pipe system in a house. Lead readily attacked by calcium hydrate (breweries); lead pipe passing through walls in contact with cement corrodes. Connection of lead to copper or brass pipes when strong electrolyte is present causes electro-chemical corrosion. Lead stretches easily producing small cracks; surface of cracks is not glossy but dark gray and granular. Fatigue may be caused by vibration (traffic in a street with pipe held fast in wall or ground) resulting in cracking. Tin pipes not generally used for domestic water. They do not corrode but are subject to "tin pest" (change in character of material, becoming crystalline). Most important in corrosion of copper pipe is O_2 in solution; CO_2 alone does not dissolve copper. Formation of protective coating by lime salts is exceedingly slow. The Copper Pipe Commission has found that 3 p.p.m. of Cu is allowable in water standing 16 hrs. in copper pipes. Water of 132 Netherlands pumping stations (out of total 149) can be led through unprotected copper piping. The Comm. has given specifications for tinning pipes: weight of tin 30 grams per sq. meter or layer of about 0.004 mm.; density sufficient to prevent solution of more than 0.5 mg. Cu. per 100 sq. cm. tinned surface; lead content low. Investigations to date indicate that copper pipe not readily attacked by soil solutions, but caution is warranted. Copper lined pipe placed in

peaty soil was considerably corroded after 8 yrs.; possibly because of tin layer. Copper pipe buried in cinders showed hole corrosion (electrolytic corrosion). Combinations of lead and copper piping corrode more rapidly. Brass, bronze and zinc withstand corrosion better, but brass portions in copper pipes corrode rapidly. Considerable experimental work underway. *Corrosion Prevention.* Methods for removal of O_2 by subjecting to vacuum or contact with binding material are not used; deacidification is practiced by aeration, followed by treatment over marble to combine remaining CO_2 acidity; or with lime as slurry or in solution; some non-aggressive CO_2 remains. If CO_2 gas is less than non-aggressive CO_2 the soluble double salt precipitates as non-soluble bicarbonate. The same happens if too much hydrated lime is added. This may form protective coating. Protection by uniform asphalt layer 1-2 mm. thick for inside, thicker for outside held with jute. If not properly applied or improper pipe material coat loosens; problematical whether thick layer is better. Good pipes with 1 mm. cover, protected by light colored paper to prevent action of sunlight and soil damage, have proven to be effective. Useful period should be unlimited when well isolated and no cracks are present. Centrifugally produced pipes are about 30% denser than those cast in sand, although thinner they last longer. *Choice of Material.* For steel or c. i. pipe safety factor is large; c. i. pipe 300 mm. dia. and 13 mm. thick stands pressure of 100 kg./cm.^{2}, while ordinary pressure is only 3-4 kg./cm.^{2}; stresses caused by caving or shrinking of soil and temperature changes must be considered,—stretching, bending. Through experience with difficulties eternite [asbestos cement] pipes with collars and rubber rings or flanges have come into use, resulting in less breaking. For indoor piping steel, lead and copper are used; in most cases tinned steel pipes are not recommended for hot water systems: corrosion, obstruction of flow. For cold water most piping is lead, but is considered undesirable if neat work is required. Copper is better. From toxicological standpoint lead, copper and zinc may be dangerous; lead most, because part of lead is retained in human body. This is not true with copper and zinc. Allowable quantities of lead and copper are given, for zinc no figures available. Copper used in 3 grades, soft, medium and hard: tensile strength 22, 25, and 28 kg./mm.^{2}—*Willem Rudolfs.*

The Corrosion of Iron and Lead in the Soil. V. S. Daniel'-Bek, O. L. Leikhman, O. K. Ritter and N. A. Zhakova. J. Applied Chem. (U.S.S.R.) **11:** 567 (in French 587) ('38). Corrosion of samples of Pb (99.97% pure) and Fe in 69 samples of artificial and natural soil of various moisture contents was investigated. Differences in wt. before expts. and after removal of corrosion products and appearance of specimens were used to evaluate degree of corrosion. Sol. chlorides in soil cause greatest corrosion of Fe: sol. sulfates are next most active, and sol. nitrates third. Sol. carbonates retard corrosion, and in sufficient amt. entirely prevent it. Slightly sol. carbonates have no visible effect on corrosion of Fe. Sol. humus content and total acidity of soil have some influence on Fe corrosion, but total humus content has no relation to corrosion activity. Moisture is main factor in corrosion of Fe. Air permeability of soil with moderate moisture content does not affect Fe corrosion unless permeability is decreased a great deal. Content of org. acidic sub-

stances in soil is main factor in Pb corrosion. Thus, with increase of total humus, sol. humus and acidity of water ext., corrosive action of soil increases. Content of sol. salts and slightly sol. carbonates has no effect on Pb corrosion. Coarseness and air permeability of soil promote Pb corrosion. Increase of moisture content of soil also promotes Pb corrosion, provided there is sufficient air penetration. Detns. of humus and chloride contents, pH of water ext., oxidizability of water ext. and dry residue of water ext. are recommended as measures of corrosive action of soil on Pb cable. Peat soil and all soils very high in humus are most corrosive to Pb. Salt-contg. and peat soils are most unfavorable for Fe. Eighteen references.—*C. A.*

Relation of Soil Properties to Corrosion of Buried Steel. WALTER F. ROGERS. Ind. Eng. Chem. **30:** 1181 (Oct. '38). Laboratory tests were made on 3 soils of different types, 2 of low resistivity, one corrosive and one non-corrosive in the field, the other a sand of high resistivity. Cleaned 1" squares of 20 gage cold rolled steel were buried in 100 grams of the prepared soil for 7 days in 4 oz. glass jars at laboratory temp., cleaned in hot sodium hydroxide and zinc soln., and loss of wt. detd. The soils were treated to vary pH, resistivity and water-air volume. Field data also obtd. from 213 samples taken when 3 oil field lines were repaired. Conclusions are: (1) Controlling factor in soil corrosion of buried steel is effect of variations in the soil water-air proportions. Laboratory variations of these factors allowed variations in corrosion rates of 31.1:1 to 56.5:1 to occur. (2) Varying electrical resistivity from 12,000 to 94 ohm-cm. for a given soil in the laboratory resulted in a variation in corrosion rate between 1.5 and 1. (3) Varying the pH of a slightly buffered sand between 4.5 and 9.75 varied corrosion rate between 2.2 and 1. (4) Very few corrosive soils have resistivities greater than 1800 ohm-cm., though most soils have resistivities lower than 1800 ohm-cm. (5) Comparison of soil pH values with field corrosion rates indicates complete lack of correlation. The method cannot be used as a field index of soil corrosion. (6) Corrosion rate of a soil in the field may be detd. by following its seasonal variations in water-air volumes and checking against a laboratory index test.—*Selma Gottlieb.*

Cathodic Protection (Combating Pipe Corrosion with Electricity). A. V. SMITH. J. N. E. W. W. A. **52:** 233 (Jun. '38). Corrosion explained in elementary terms using water flow as analogy. Current flowing from pipe to point of lower potential causes corrosion; may be caused by stray currents as from electric street railways or by currents generated by local conditions, galvanic currents. Cathodic protection used to reduce galvanic corrosion. Galvanic currents may be due to impurities in metal, dissimilar structure, dissimilar metals in contact and dissimilar soils in which pipe lies. Cathodic protection achieved by causing pipe to become cathode instead of anode and have currents flow to pipe rather than away from pipe; carried out by installing an anode and current source at suitable locations along pipe line. Has been successfully used on single pipe lines in areas where other pipe lines not involved, in other locations such protection requires careful study and may be applied successfully only in special cases. Any abnormal resistance in a pipe carrying current will produce hazardous condition under cathodic protection, may occur at

screw joints, Dresser couplings, compound joints, lead joints, mechanical joints, valves, etc. Doubtful if cathodic protection necessary for c. i. dist. mains.—*Martin E. Flentje.*

Pipe Corrosion, Electrolysis and Cathodic Protection. A. L. BLACK. Penna. State Coll., Mineral Ind. Expt. Sta. Bull. No. 21, 79 ('37). Electrolytic corrosion of pipe is discussed. Waterproof painting offers inadequate protection. Bonding insulating material to pipe gives trouble. Enamel chips. Grease coatings do not stand up. Cathodic protection in connection with suitable coatings seems most effective.—*C. A.*

Outbreak of Food Poisoning Due to Toxic Tin Compounds. CURTIS E. MONTREY. Southwest W. W. J. **20**: 11: 25 (Feb. '39). Illness developed by soda fountain customers in Newkirk, Okla., within a few minutes after drinking carbonated drinks. First sign of trouble was bad taste in the carbonated drinks. After washing carbonator and tubing with hot soda water trouble disappeared for several days, then reappeared. Changing the gas drum, using new syrups from freshly opened kegs and reducing the gas pressure from 120 to 90 lbs. had no effect. All of the carbonated drinks were checked for taste and odor, and both the drinks and the carbonated water were found to have a metallic bitter taste. No off odors were present. Similar investigations at three other drug stores in the same town showed nothing unusual and indicated that the city water supply was not at fault. When the effected carbonator was dismantled the block tin wall was found discolored and corroded whereas ten or twelve months before, inspection had shown it to be in good shape. Examinations of bottom of carbonator and of city water were made by Oklahoma Health Department. Bottom was found to be decidedly crystalline in nature, with corrosion carbuncles which were partly soluble in water. Laboratory concluded that the toxic material was possibly tin chloride formed as result of electrolysis due to stray currents in or near the carbonator. Stray current tests showed all of the pipe in the basement including water, gas, sewer, ammonia and carbonated water lines, were carrying stray current and several of the pipes were in contact with the 110-volt lighting circuits. Carbonator was not grounded. All buildings in the block were checked for stray currents and wiring in two of them was found defective. When these defects were corrected, the light circuits removed from the pipes in the drug store basement, a new carbonator and new lines installed, and the carbonator grounded, the stray currents were cleared up and no more trouble has been experienced. Stated that absence of a ground on the carbonator probably prevented wiring defects from blowing the fuses so that stray currents persisted indefinitely. Also stated that since alternating current cannot cause electrolysis some rectification action must have taken place between the block tin bottom of the carbonator and the iron plate on which it rested. When this bottom was examined 99% of the incrustation was found on the bottom plate. Article concludes with statement that it would seem advisable for all sanitarians and health officials to look more closely at the wiring in drug stores and other food handling establishments.—*Charles F. Meyerherm.*

Pretreatment of Metal Surfaces for Painting. F. N. SPELLER. Ind. Eng. Chem. **30**: 1152 (Oct. '38). Adhesion of paints to metals is hampered by presence of moisture or loose foreign matter. Tightly bonded, stable, and absorptive surface films (e.g., oxides, phosphates or chromates) usually afford a better surface for painting than the metal itself. Warming the metal assures a dry surface and also improves strength of bond to coating. Composition of metal is of some importance since it governs properties of the surface film formed in air. Chemical action between the metal and decomposition products of the paint vehicle may loosen the bond, e.g., reaction between most oil paints and a new hot-galvanized surface, resulting in corrosion. Changes in strength and ductility of the paint film also tend to destroy adhesion. Best and most economical practice of surface treatment will be determined by many factors, including cost and surface conditions; e.g., author considers removal of mill scale sometimes necessary, sometimes not. Metal surfaces can be cleaned by weathering, sand- or steel-grit blasting, brushing, sulfuric acid pickling alone or followed by a 2% free phosphoric acid bath containing approx. 0.5% iron in soln., for 3 to 4 min. at 185° F. The pipe is dried without washing and paint applied over iron phosphate coating while warm. Last traces of moisture film can be removed from a pipe with gas flame immediately before painting. Inhibitors may be used to retard or prevent electrochemical corrosion, e.g., zinc chromate or red lead in priming coat, or pretreatment with aqueous phosphate or chromate solns. Effect is due to adherent films combined with passivating effect. All foreign matter not tightly bonded to the metal or not suitable as a paint base should be removed. Author considers most desirable preparation of steel surfaces for painting is complete descaling, followed by phosphating or similar chemical treatment. Practical value of low-cost water solutions of inhibitors to fabricated or structural steel has not been fully demonstrated by long-time tests in service.—*Selma Gottlieb.*

Effect of Corrosion on the Durability of Paint Films. V. M. DARSEY. Ind. Eng. Chem. **30**: 1147 (Oct. '38). Durability of paint coatings on different metals depends greatly on corrodibility of metal under conditions of use. Tests were made on various metals, including steel, galvanized iron, aluminum, and stainless steel. Test panels (4" x 12") of stainless steel were acid or alkali cleaned only, but for other metals some panels were solvent cleaned only while others were alkali-cleaned and then "Bonderized" in a phosphate rust-proofing soln. to convert the metal surface to a non-metallic phosphate coating. These panels painted with various paints were exposed in salt spray and controlled humidity cabinets and in Florida outdoor atmosphere. In salt spray and outdoor tests, painted panels were purposely scratched. Results showed that corrosion was primary cause of paint failure, since when moisture penetrates a paint film, deleterious effect depends on amt. of corrosion resulting. Paint failure can be retarded by corrosion-inhibiting treatment of underlying metal, or corrosion-inhibiting substance in the paint.—*Selma Gottlieb.*

Corrosion and Erosion in River and Harbor Structures. FERD DIEFFENBACH. Ind. Eng. Chem. **30**: 1014 (Sep. '38). Report of investigations by

Corps of Engineers of U. S. Army in Pittsburgh Engineer District (PED), on maintenance of river and harbor structures, esp. on Monongahela R. The water is acid, and suspended sand keeps metal surfaces scoured clean for further corrosive action. Lock and harbor machinery and equipment, construction machinery used in the river, etc., suffer severe corrosion-erosion. Acid water pollution comes chiefly from mines, with iron and steel mills, including pickling operations, oil production and refining, paper mills, tanneries, and absorption of acid anhydrides from the air, also contributing. Acid content of river water shows great variation from time to time and at various locations, water showing alkalinity at certain times. PED recommends for corrosion prevention, under normal or usual conditions, a China wood and varnish oil paint fortified by polymerization with phenolformaldehyde resin. Composition is: *Prime coat,*—red lead, 16.45% by wt.; iron oxide, 38.25%; raw linseed oil, 4.64%; zinc yellow, 5.58%; diatomaceous silica, 5.92%; pine oil, 1.08%; *n*-butyl alcohol, 0.23%; vehicle, 27.85%. *Finish coat,*—carbon black, 5.0%; vehicle, 95.0%. *Vehicle* for both coats,—mineral spirits, 28.12%; varnish oil, 17.15%; phenol-formaldehyde resin, 16.65%; China wood oil, 25.98%; dipentine, 4.67%; ethylene glycol monoethyl ether, 3.84%; toluene, 2.38%; high flash naphtha, 1.21%. Material specifications and manufacturing process are given in detail Paint has lower original cost than red lead-linseed oil paint, and costs less to apply because of free-flowing properties. The vehicle described has been adopted as standard by the PED for all paints except white and, used alone, as the standard spar varnish for both indoor and outdoor work. In more severe conditions where mechanical wear and abrasion exist and where mechanical strength is a prerequisite, corrosion-erosion resistant materials of construction must be used. Cast iron with 0.8-1.0% copper and 0.4-0.55% molybdenum gives materially better results than cast gray iron or cast steel, e.g., in lock gate valves. In hydraulic turbine runners, valve frames, speed rings, etc., cast iron with 13.0-16.0% nickel, 5-7% copper and 2.0-3.5% chromium has given excellent results. Corrosion-resisting steel, either alone or clad to mild carbon steel, has many applications. It contains 16-20% chromium, 7-14% nickel, and 2-4% molybdenum. It may be obtd. in rolled, forged or cast form, but cannot be hardened by heat. Martensitic steel containing 12-15% chromium and 0.5% max. molybdenum can be heat treated. For bearings operating with steel in acid river water, following bronze has given excellent results: copper, 79.25-80.25%; tin, 9.5-10.5%; lead, 9.5-10.5%. Complete chemical analyses of all above alloys are given. A boiler compound successfully used for steam boilers using raw acid river water contains: soda ash 61%; sodium phosphate monohydrate, 18%; sodium hydroxide, 13%; tannates, 8%. Process treatment of water within mills helps somewhat to alleviate river acidity. For approx. detn. of suitability of corrosion-erosion resistant materials, PED has developed testing machine consisting essentially of a tank equipped with a series of nozzles through which a sulfuric acid soln. containing sharp river sand is pumped over test pieces fixed to a bar submerged in the soln. Other tests are made by placing actual specimens in spool form on rods and submerging on fixed frames in the river, but actual use of the material in the particular service contemplated is the only 100% accurate test.—*Selma Gottlieb.*

Biological Factors Affecting Paints on Submerged Constructions in the Sea. C. BARENFANGER. Chem. Z. **62:** 461 ('38). *Paper before Water Chemistry Sect. Verein Deutscher Chemiker, June '38.* Progress in prevention of growths on painted structures in sea water can only be made after systematic study of the biology of organisms which cause damage. The harmful organisms may be divided into three classes: those which cause change of color, those which alter the surface structure of the paint, and those which develop in masses as on ships, increasing the surface area. Some organisms can bore through the softer layer of paint and expose the underlying material to the sea water. There are materials which will prevent these boring animals from penetrating the paint.—*W. P. R.*

Benzyl Cellulose, A New Type of Rust-Preventing Agent. H. KALPERS. Rdsch. Tech. Arb. **51:** 9 ('38); Wass. u. Abwass. **36:** 40 ('38). Describes use of benzyl cellulose in preventing formation of rust on metallic surfaces. Metal surface is treated with a solution of the compound in an organic solvent and the resulting coating, which adheres firmly to the metal, is resistant to attack by the atmosphere or by water. This reagent is of value in preventing underwater corrosion. List is given of solvents which may be used.—*W. P. R.*

Film Inhibitors in Industrial Aqueous Systems. DAVID W. HAERING. Ind. Eng. Chem. **30:** 1356 (Dec. '38). Where repeated aeration of water is essential to industrial processes, e.g., cooling systems, oxygen control is impractical if not impossible, and corrosive characteristics of waters are increased by repeated contact with atmospheric gases. Strongly adherent organic film inhibitors such as chrome glucosate (CG) are successful in retarding corrosion in such systems. Quantity of CG needed depends on nature of water and on metal area exposed. Careful control tests must be made to detn. amts. needed to form and to maintain protective film. For routine field control, CG in soln. is detd. by direct color comparison tests. Normally 125 p.p.m. of CG is sufficient to insure immediate film formation in absence of sulfide, or 250 p.p.m. of CG in presence of sulfide, either from hydrogen sulfide originally present in the water or introduced thru anaerobic bacterial decomposition of sulfate. Dosage in makeup water will vary with % of makeup; system residual is ordinarily maintained at 50 to 125 p.p.m. Results are best with a scale-free system. Using film inhibitor, solids concn. of water may be allowed to increase, with consequent saving of water. Author concludes that results obtd. from use of film inhibitors in large-scale operations have justified cost of inhibitor.—*Selma Gottlieb.*

Bituminous Enamel Bond Strength. O. G. GOLDMAN. Eng. News-Rec. **121:** 339 (Sep. 15, '38). Device, developed by author, for determining bond strength between primer coat on steel pipes, etc., and bituminous enamel is described. Specimen is coated with primer under definite conditions and then cups of molten enamel are placed against it and allowed to cool to room temp. Pressure required to pull cups from specimen indicates bond strength, max. attainable being, of course, the tensile strength of the enamel, in which case enamel

will break in cup. By varying drying period for the primer coat and the temp. of application, optimum conditions can be determined.—*R. E. Thompson.*

Use of Bitumen-Coated Steel Pipes Inside Houses. E. FLEISCHMANN. Pumpen-u. Brunnenbau, Bohrtech. **33**: 339 ('37); Wass. u. Abwass. **35**: 241 ('37). The prohibition of the use of lead and copper pipes in houses has given steel added importance. The bitumen-coated "Habit" pipe has an inner protective layer 1–2 mm. thick which is completely stable, protects the pipe from aggressive water, and prevents reduction of capacity by rust deposits.—*W. P. R.*

Resin Coatings. M. C. SMITH. Product Eng. **9**: 8: 303 (Aug. '38). Resin coatings which can be applied cold by means of ordinary paint-spray equipment or brushed on cold are described, and results of accelerated laboratory and field tests on resistance to abrasion and chemical attack are given. Coating schedule consists of prime, body, and seal coat, constituents of each varying with material to be protected and the corroding medium. Tensile strength of the coating was tested to av. about 300 lbs. per sq. in. in 18 tests. The material is practically insoluble in any ordinarily encountered corrosive agency except the true aromatic hydrocarbons which are the natural solvents.—*T. E. Larson.*

The Corrosion Effect of the Deformation of Steel Pipes for Water Lines. ADAM SKAPSKI AND EUGÈNE CHYZEWSKI. Métaux Corrosion **13**: 21 ('38). Polished steel pipe rings were subjected to mech. deformation by screwing a nut on a bolt passing through diam. of pipe and immersed in 6 different corrosive solns. It is concluded that static deformation does not influence speed of corrosion of steel pipes in corrosive medium of pH greater than 4 but accelerates corrosion in solns. of pH 2.0. Eighteen references.—*C. A.*

The Stability Toward Sea and River Water of Metallic Coatings Applied to Steel by Atomizing. I. YA. KLINOV. J. Applied Chem. (U. S. S. R.) **10**: 1366 (in French, p. 1379) ('37). Stability of ordinary steel coated with Zn, Zn and Cd, Cu, Cu with intermediate layer of Zn, and Sn in artificial solns. corresponding to several natural waters was tested. In all cases, best coatings were Zn and Zn + Cd. Layer 0.03 mm. thick is sufficient protection against corrosion. Four references.—*C. A.*